Failures in monitoring text comprehension: An explanation in terms of the Construction-Integration model

Jose Otero

Institute of Cognitive Science
University of Colorado
Boulder, Colorado 80309-0345
303/492-8663

Institute of Cognitive Science
Publication Number 90-17

Failures in monitoring text comprehension: An explanation in terms of the Construction-Integration model.

Jose Otero

Acknowledgements: This project had not been possible without the help of Walter Kintsch. I thank him for the time and interest he took on this work. Eileen Kintsch helped decisively to change my writing into readable English and made many valuable suggestions on the organization and content of the report. Paula Schwanenflugel also made comments most helpful in clarifying this presentation. I thank both for their help. The project was carried out while the author was on sabbatical leave from the Universidad de Alcala (Madrid), supported by a Grant from D.G.I.C.Y.T. of the Ministry of Education, Spain.

The detection of inconsistencies in manipulated texts has been a task frequently used by researchers interested in the study of comprehension monitoring abilities. Individual and age differences in the detection of text contradictions, as well as differences related to the type of inconsistency which is to be detected (falsehoods or textual contradictions or, in Baker's terms [1985b], internal or external inconsistencies) have been found by a number of researchers (Baker, 1979, 1985a; Baker & Anderson, 1982; Glenberg, Wilkinson & Epstein, 1982; Markman, 1979; Markman & Gorin, 1981; Otero & Campanario, 1990; Vosniadou, Pearson & Rogers, 1988). However most of the work on the subject has been descriptive. The purpose of this report is to present a partial explanation of the failure to detect a contradiction in terms of the Construction-Integration (C-I) model of text comprehension (Kintsch, 1988).

1. The Construction-Integration Model of Text Comprehension

The C-I model attempts to explain the way knowledge is used in understanding discourse. It inherits some of the characteristics of the previous Kintsch & van Dijk's models of text comprehension (1978; van Dijk & Kintsch, 1983). Texts are processed in cycles, and the resulting representation of the text in memory is propositional. Memory is conceived as an associative network whose nodes consist of concepts or propositions with activation spreading among them. Two stages are distinguished in the operation of the model. First, there is a construction phase in which text propositions resulting from parsing the text (a stage which is not dealt with by the model) are joined together with a variety of concepts and propositions retrieved from memory. General knowledge propositions and concepts are retrieved at this stage without regard for their contextual adequacy. Both text and general knowledge propositions are interconnected using argument overlap as a default criterion. Connection strengths are assigned to these links, creating a connectivity matrix. These strengths are parameters which are estimated to provide and adequate fit to the data. They may be positive or negative, the latter corresponding to inhibitory connections.

The second phase consists of an integration process carried out in the connectionist manner. The spread of activation between propositions is calculated by repeatedly multiplying the connectivity matrix by a vector whose components are the activation values of each proposition. Following each multiplication negative values are set to zero, and the vector is normalized. After a few iterations the vector is usually stabilized, giving as a result the final activation level of the propositions. In this way the model achieves with "dumb rules" what has been usually done by means of smart procedures (i.e., schemata, frames, or scripts). Inappropriate concepts or propositions are filtered out in the integration phase; activation is only accumulated in the contextually relevant nodes.

2. Empirical evidence of comprehension monitoring failure

Readers react in different ways to an explicit contradiction in a text (Otero & Campanario, 1990). First, it is possible to overlook the contradiction and be completely unaware of its existence. In this case evaluation of comprehension is inadequate. Second, it is possible to notice the contradiction but do nothing to restore coherence in the text; or the reader may take inapropriate measures to solve the incoherence and remain satisfied with an incomplete comprehension. In this case, evaluation of comprehension is adequate but regulation is inadequate. Third, it is possible to detect the contradiction and reject the text as incoherent, explicitly pointing out the problem. This implies both adequate evaluation and regulation of comprehension. Campanario & Otero (1989) found individual differences in the way secondary school students deal with contradictory texts, according to these categories. Figure 1 shows clusters of 10th- and 12th-grade students who processed four contradictory texts in a similar way(). The x-axis represents the percentages of students in each cluster. The sum does not add up to 100 because the processing of the texts for a small fraction of the students was too heterogeneous to be included in any cluster. The y-axis represents the mean number of texts (with a maximum of 4) processed according to the comprehension monitoring categories mentioned above. As seen from the figure, there are both in 10th- and 12th-grade clusters which differ noticeably from each other, indicating individual differences in the comprehension monitoring abilities of subjects. A progression is also apparent from an important percentage of nondetectors in the 10th grade (70% cluster) to a majority of detectors and good regulators in the 12th-grade (67% cluster).

The simulation presented below is concerned with the first type of situation mentioned above: being unaware of the existence of an explicit contradiction after having read a manipulated text. The processes to be simulated correspond to an experiment carried out with minor methodological differences with respect to the two studies just mentioned. Since a complete report of the basic design and results can be found in Otero & Campanario (1990), only a brief description of the relevant points of this last experiment will be given here.

Method

Subjects and materials

There were 116 10th-grade students and 102 12th-grade students, from four public schools in Madrid who participated in this study. During one of their class periods the students read the six short texts used in all of the experiments, four of which involved explicit contradictions. The simulation presented below is only concerned with one of these texts:

Text #3 Superconductivity

> Superconductivity is the disappearance of resistance to the flow of electric current. Until now it had only been obtained by cooling certain materials to low temperatures near absolute zero. That made its technical applications very difficult. Many laboratories are now trying to obtain superconducting alloys. Many materials with this property, with inmediate technical applicability, have been recently discovered. Until now superconductivity had been achieved by considerably increasing the temperature of certain materials.

The contradictory statements were always located in the second and last sentences.

Procedure

The experiment consisted of two phases. First, the students were instructed to read the texts and indicate, in writing, any difficulty which they might find, although they were not explicitly warned of the existence of contradictions. In addition, they had to rate the understandability of the text on a scale ranging from 1 to 4. The texts were taken away and, before starting the next phase, the subjects were asked to write down as much as they remembered from each text. Afterwards, a new booklet was handed to the students which informed them about the contradictions in the texts. The purpose of this second phase of the experiment was to ascertain whether all of the students who did not underline the contradictory sentences had been aware of the problem or not. We had found, in all of the experiments, that some of the students had detected the contradictions in the first phase but failed to report them because they had used novel "repair" procedures (Baker, 1979). They made inferences which, in their view, explained the contradictions. For example, in the superconductivity text the most frequent inference was assuming that methods for obtaining superconductivity were different in the past than nowadays. The instructions in the booklet required these students to explain the reasons for not explicitly pointing out the contradiction in the first phase.

Scoring

The data provided by the subjects in the two booklets (detection of the contradiction in the first phase, comprehensibility score, explanation given in the second phase), together with information obtained from individual interviews conducted at the end of the session, were used to categorize comprehension monitoring for each text with respect to the evaluation and the regulation components mentioned above. Thus, for a given text: a) evaluation of comprehension is inadequate, b) evaluation is adequate but regulation is inadequate, and c) evaluation and regulation are adequate. As the simulation only concerns the first of these situations, only the recall protocols of the subjets who did not detect the contradiction in the superconductivity text were analyzed. We used an informal criterion in scoring their recall. A sentence was counted as mentioned when the actual text propositions appeared in the written protocols (for example, "Superconductivity is the disappearance of resistance [745]") or when a paraphrase acceptable to the scorers was given (for example, "Superconductivity consists in electric energy flowing without difficulty [701]"). Two independent scorers analyzed these responses, reaching a 90.8% agreement on the classification of the written statements. The remaining discrepancies were resolved by discussion.

Results

Figure 2 shows percentages of the 88 nondetectors (40.3% of the students) mentioning information from each of the six sentences of the superconductivity text. As seen from the figure, there is a decrease, for both grades, in the information mentioned as one proceeds through the text. The definition of superconductivity in the first sentence is the information most frequently mentioned, followed by "superconductivity is obtained by cooling", but few of the nondetectors say that superconductivity is obtained by increasing the temperature.

In Figure 3 the nondetectors are classified according to their pattern of recall for the first, second and last sentences. The following categories are used:

Type I: Subjects who only mention the definition of superconductivity and do not report information associated with the contradictory propositions. For example:

It is the flow of electric current without any obstacles (773).

Type II: Subjects who mention that superconductivity is obtained by cooling, or an acceptable paraphrase, without also saying that it is obtained by increasing the temperature. For example:

> It is the process by which one attempts to minimize the resistance of materials to be traversed by electric energy. This has been achieved at temperatures near absolute zero, which makes it unprofitable and inefficient (796).

Type III: Subjects who mention that superconductivity was formerly obtained by cooling and now is obtained by a new means, or an acceptable

Figure 1a. Clusters : evaluation and regulation abilities of 10th-grade students.

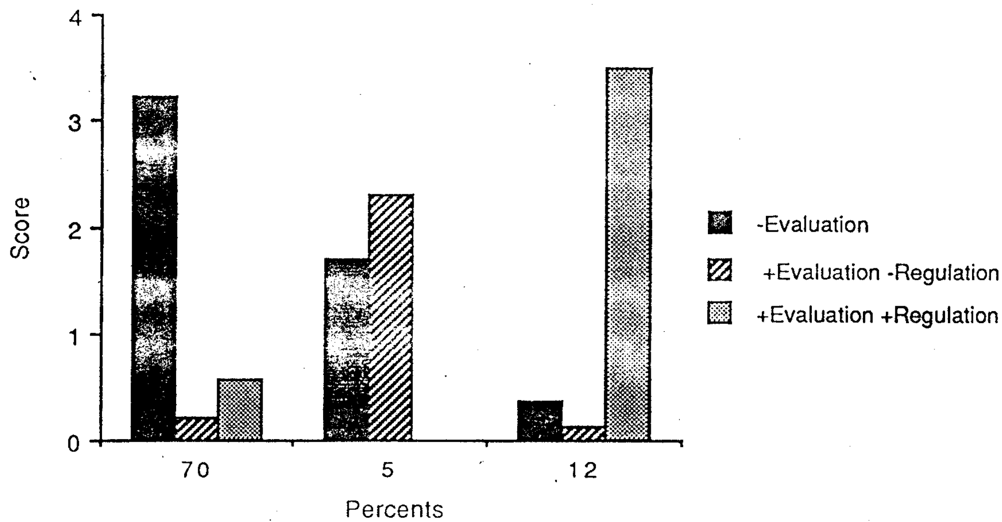


Figure 1b. Clusters: Evaluation and regulation abilities of 12th-grade students.

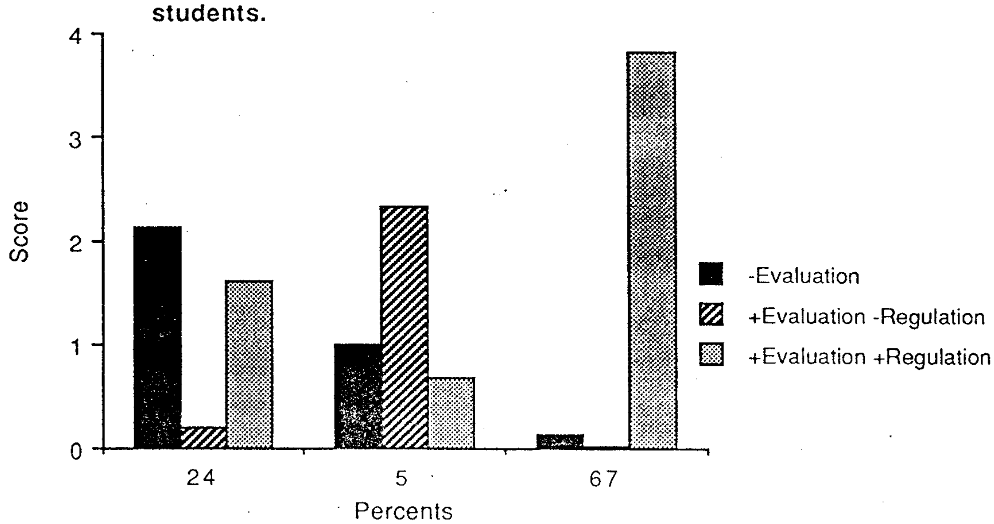
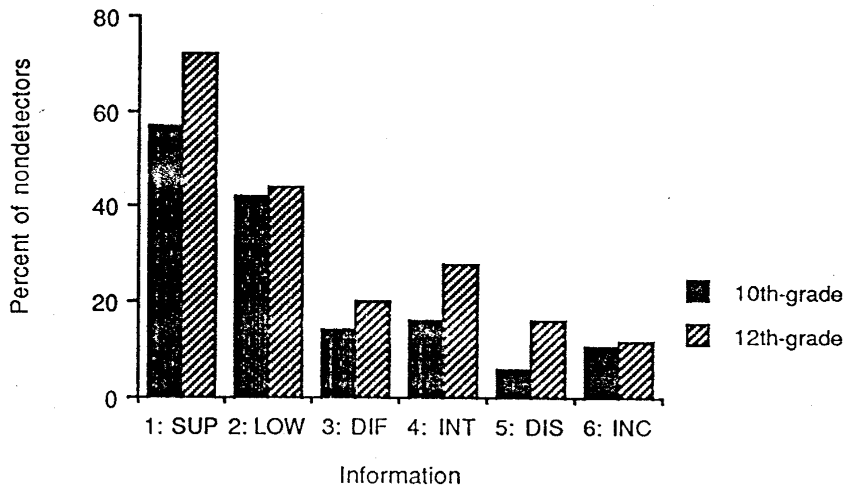


Figure 2. Percentage of nondetectors mentioning information from each sentence in the superconductivity text.



paraphrase. Two of the subjects mention explicitly as a new means, "increasing the temperature", as in the second example below:

Until recently one could not say that a material was a conductor (sic) unless it was submitted to a treatment that would set it almost to 0 degrees, but now there are some superconducting materials which do not need this treatment (607).

...Initially, in order to get superconductivity, one must submit the materials to very low temperatures. The studies on the subject have been able to prove that it is possible to achieve it by other methods such as setting some materials to very high temperatures (806).

Type IV: Subjects who mention that superconductivity is obtained by increasing the temperature, or an acceptable paraphrase, without also saying that it is obtained by cooling. For example:

It is achieved when all obstacles to conduction are made to disappear and this is achieved when the temperature of certain materials is elevated (530).

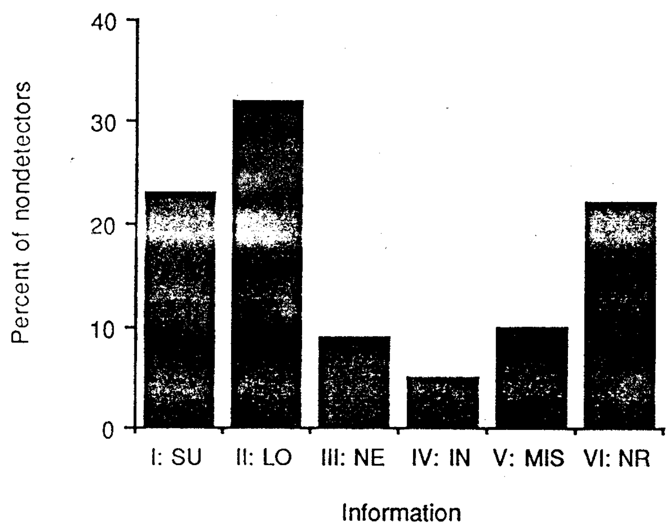
Type V: Subjects who give a variety a responses, not classifiable under these categories. For example,

Superconductivity is the flow of electric current and that in superconductivity [sic] alloys are formed (527).

Type VI: Subjects who do not recall anything.

Figure 3 shows that there is a relatively important percentage of nondetectors who only mention the definition of superconductivity. It should also be noted that there are many more subjects who remember "cooling" as the method of obtaining superconductivity, than those who mention "increasing the temperature".

Figure 3. Patterns of recall of Information from the first, second, and lasr sentences.



On the basis of these data, the C-I model will be used to simulate possible processes leading to an evaluation problem, i.e., to non-detection of the contradiction. The simulation will be carried out for readers who are in situations I, II, and III above. Situation IV is not considered because of the small number of subjects showing this recall pattern. Nor is situation V taken into account, as these responses contain information not related to the target sentences or they are agrammatical or meaningless sentences.

The procedure used to simulate the overlooking of contradictions is also applied to another instance of comprehension monitoring failure: the so called "Moses illusion" (Erickson & Mattson, 81).

3. Simulation

The text was propositionalized according to the representation system first proposed by Kintsch (1974). Six processing cycles are distinguished in the simulation, corresponding to sentence boundaries. A necessary () condition for detecting a contradiction in a text is that the two contradicting propositions be active simultaneously in working memory. Thus, in order to detect the contradiction in this text, P25: OBTAIN (SUP, COOL) from the second cycle and P64: OBTAIN (SUP, INCREASE) from the last cycle (Figures 6 and 10) should be active, together with their arguments, when the reader processes the last sentence (). Accordingly, failure to detect the contradiction could be caused by any of the following situations in the last cycle:

a) Neither P25 nor P64 is active.

b) P25 is active but P64 is not.

c) P64 is active but P25 is not.

The plausibility of these three situations can be evaluated on the basis of a theoretical assumption and the empirical data presented in Figure 3. The theoretical assumption is that the probability of a proposition being recalled depends on its activation while being processed: the more highly activated propositions in each cycle will more likely be recalled (Kintsch & Welsch, in press). Hence, Figure 3 shows situation (c) to be infrequent: only 4 nondetectors recalled P64 without mentioning P25. Figure 3 also shows that there is a significant number of subjects who reported only the definition of superconductivity. For these subjects the activation of propositions not pertaining to the first sentence was probably low. These are subjects who would be in situation (a) above. Thus, the simulations in the last cycle deal only with situations (a) and (b).

As seen in Figure 1 there are individual differences in the detection of contradictions which can be attributed to the existence of careful and superficial reading habits. In terms of the model, these differences are implemented as different levels of activation for two kinds of propositions: text propositions and "biasing" propositions generated by the reader. The former are those directly derived from the text. The latter are usually macropropositions built by the reader which influence discourse processing by being part of the "control system" (van Dijk & Kintsch, 83, p. 350). In some other cases, as in the Moses text or in the case of competing "friction" and "electric" propositions, these biasing propositions could also be specific micropropositions from long term memory which are especially active. A superficial reader will be operationally defined as a reader for whom activation flows more strongly among biasing propositions than among text propositions. That would correspond to the intuition that when these readers process texts the former propositions are more heavily weighted than the latter. For a careful reader there is no such predominance of generated, biasing propositions over text propositions. These different levels of activation correspond to different connection strengths in the connectivity matrix. Thus, there are differences to be expected in the detection of contradictions, which have to do with the final activation of contradictory propositions for readers holding the same biasing propositions but with different strengths.

In the following discussion links between propositions are established by the criterion of argument overlap, except when indicated otherwise (as in the Moses text). When showing activation results, the value of the connection strengths which cause the pattern of activation will always be given in parentheses, in the following order: connection strength between text propositions, between biasing propositions, between biasing and text-positive, and between biasing and text-negative. The latter correspond to links between contradictory propositions. Thus, the connection strengths for a careful reader will always be (1, 1, 1, -2) (). For a superficial reader, as pointed out above, there will be higher values for connection strengths between biasing propositions, ranging from 2 to 5.

The simulation is carried out for the first, second, and last cyles, corresponding to the first, second, and last sentences of the text. Ignoring the intervening cycles could run the risk of not taking into account other macropropositions which could influence the outcomes of the last cycle--the point at which the contradiction is or is not detected. However, there are two reasons for this restriction. The first is that the third, fourth and fifth sentences deal with marginal information regarding the influence of temperature on the ways of obtaining superconductivity. The second is that, according to the recall data in Figure 1, the percentage of subjects recalling information from these sentences is much smaller than the percentage for the first and second sentences. Therefore it seems unlikely that macropropositions with an influence on the outcomes of the last cycle could be built on the basis of information contained in these sentences.

<u>First and second processing cycles</u>

In the first cycle, the only (biasing) proposition which is assumed to be initially active, in addition to those of the first sentence, is B1: SUPERCONDUCTIVITY, as a result of the subject having read the title. Figure 4 shows the propositional analysis and network for this cycle. The resulting activation patterns, corresponding to careful and superficial readers, are shown in Figure 5.

The two most highly activated propositions in the first cycle are P13: IS (SUP, DIS) and P14: DIS (RES) for the careful reader, and P11: SUP and P13 for the superficial reader. Because of this, P11, P13, and P14 are considered to be macropropositions, or biasing propositions B2, B3, B4, in the second cycle. They are the three most highly activated propositions for both careful and superficial readers. The propositional analysis and network for the second cycle are shown in Figure 6, and the activations of propositions for a superficial reader for three different connection strengths of the biasing propositions are shown in Figure 7. Increasing these connection strengths--corresponding to more superficial readers--results in even fewer propositions active in this cycle, mimicking the empirical finding that many readers did not recall propositions from any cycle but the first. The five most activated propositions for superficial readers, independent of the connection strength chosen, B2 (=P11): SUP, B3 (=P13): IS (SUP, DIS), B4 (=P14): DIS (RES), P21: SUP, and P25: OBT (SUP, COOL), belong to the two most frequently mentioned sentences in the written summaries of the nondetectors (Figure 2). These results are stable even when a different assumption is made about the

Text: Superconductivity is the disappearance of resistance to the flow of electric current.

Biasing information: Superconductivity.

B1: SUPERCONDUCTIVITY

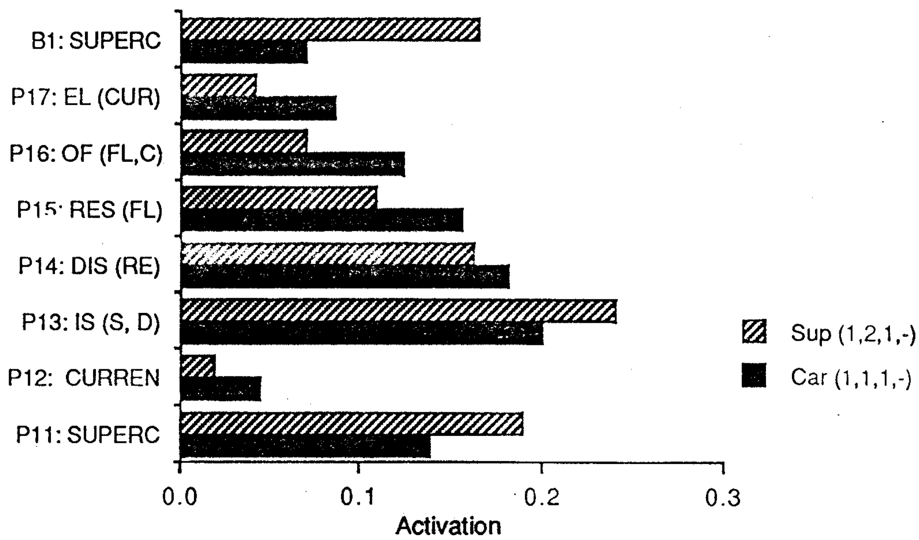
P11: SUPERCONDUCTIVITY
P12: CURRENT
P13: IS (SUPERCONDUCTIVITY, DISAPPEAR (RESIST (FLOW)))
P14: DISAPPEAR (RESIST (FLOW))
P15: RESIST (FLOW)
P16: CONSIST OF (FLOW, ELECTRIC (CURRENT))
P17: ELECTRIC (CURRENT)

```
P11: SUPERCONDUCTIVITY ———————————— B1: SUPERCONDUCTIVITY
 |
P13: IS (SUPERCONDUCTIVITY, DISAPPEAR)
 |
P14: DISAPPEAR ( RESIST (FLOW))
 |
P15: RESIST (FLOW)
 |
P16: CONSIST OF (FLOW, ELECTRIC (CURRENT))
 |
P17: ELECTRIC (CURRENT)

P12: CURRENT
```

Figure 4. Propositional analysis and network for the first cycle

Figure 5. Activations for careful and superficial readers in the first cycle.



Text: Until now it had only been obtained by cooling certain materials to low temperatures near absolute zero.

Biasing information: Superconductivity is the disappearance of resistance to flow.

B2 (P11): SUPERCONDUCTIVITY
B3 (P13): IS (SUPERCONDUCTIVITY, DISAPPEAR)
B4 (P14): DISAPPEAR (RESIST (FLOW))

P21: SUPERCONDUCTIVITY
P22: MATERIALS
P23: TEMPERATURE
P24: ZERO
P25: OBTAIN (SUP, COOL (CERTAIN(MATERIALS), LOW (TEMPERATURE)))
P26: UNTIL NOW (OBTAIN)
P27: ONLY (OBTAIN)
P28: COOL (CERTAIN (MATERIALS), LOW (TEMPERATURE))
P29: CERTAIN (MATERIALS)
P30: LOW (TEMPERATURE)
P31: NEAR (LOW (TEMPERATURE), ABSOLUTE (ZERO))
P32: ABSOLUTE (ZERO)

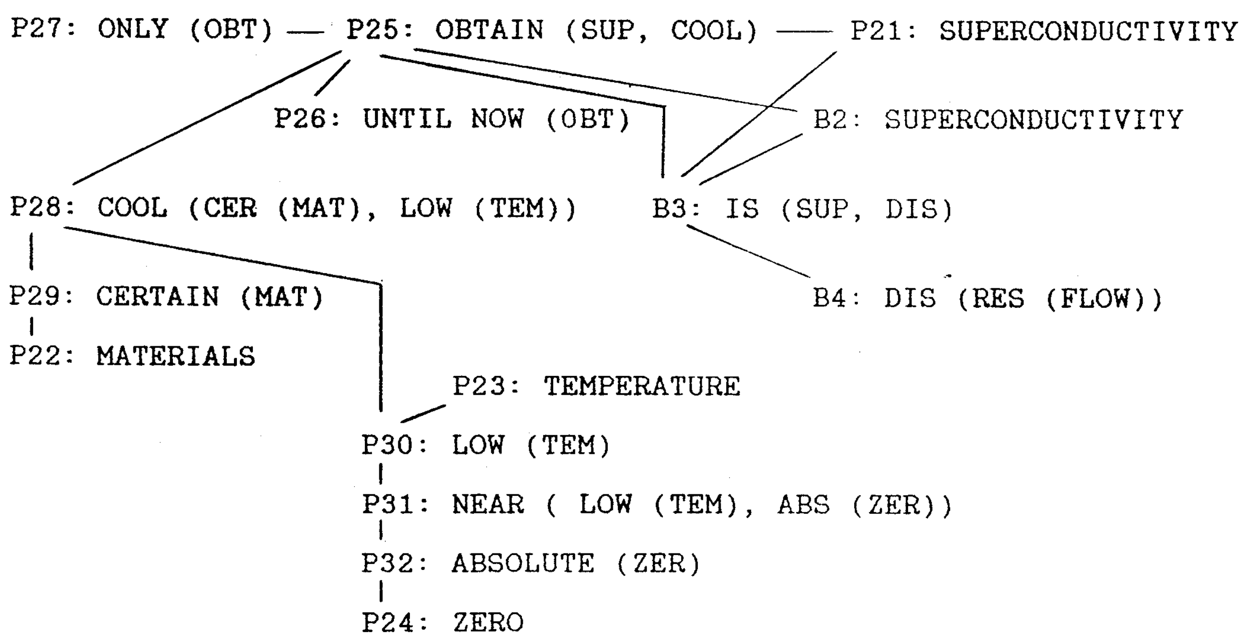
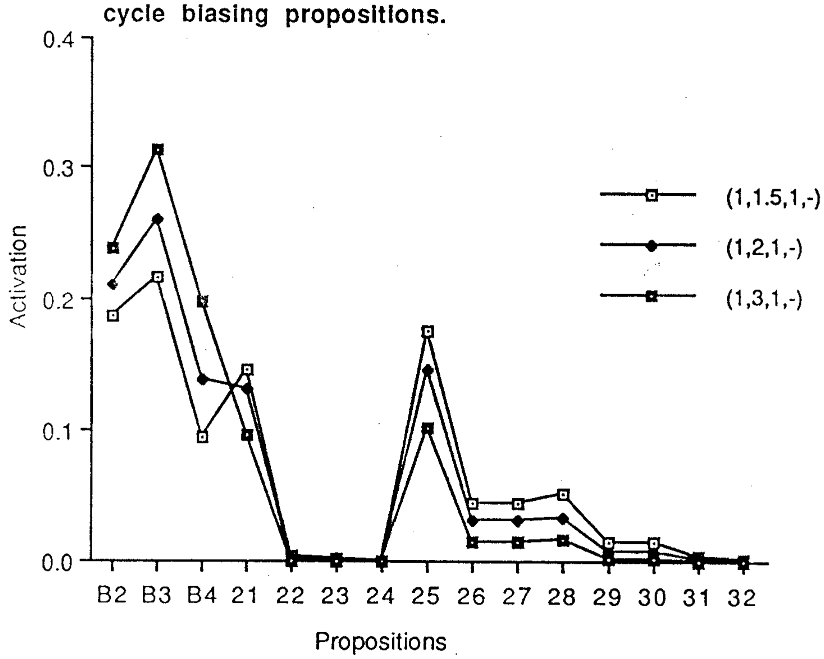


Figure 6. Propositional analysis and network for the second cycle

Figure 7. Superficial reader: activations for different connection strengths of second cycle biasing propositions.



propositions carried over from the first cycle: in Figure 8 activations are compared for the cases in which the biasing propositions are either P11 and P13, P11, P13 and P14 (the propositions actually used in Figure 7), or P11, P13, P14 and P15.

The activation of propositions in the second cycle for a careful and a superficial reader are compared in Figure 9. Here we see that the biasing propositions for the superficial readers are more highly activated than most text propositions, whereas for careful readers there is no such predominance of the biasing propositions.

Last processing cycle

In the last cycle different biasing propositions may enter the construction phase as macropropositions. As we have shown, different propositions are recalled by different types of nondetectors. We shall assume that what nondetectors recall is an indication of the kind of biasing macroproposition that controlled processing during the last cycle. Hence, the biasing propositions entering the following simulations of the last cycle correspond to the first three recall situations distinguished in the empirical results.

Superficial readers: Type I

These are the nondetectors who only mention in their written recall the definition of superconductivity. We should expect P64: OBTAIN (SUP, INC) to obtain a low activation level among these readers. Otherwise there would be a substantial number of subjects who included both a superconductivity definition and P64, that is, who mentioned that temperature has to be increased to achieve superconductivity. However, this was only found for one subject.

Figure 8. Second cycle: activations for a superficial reader, for different biasing propositions.

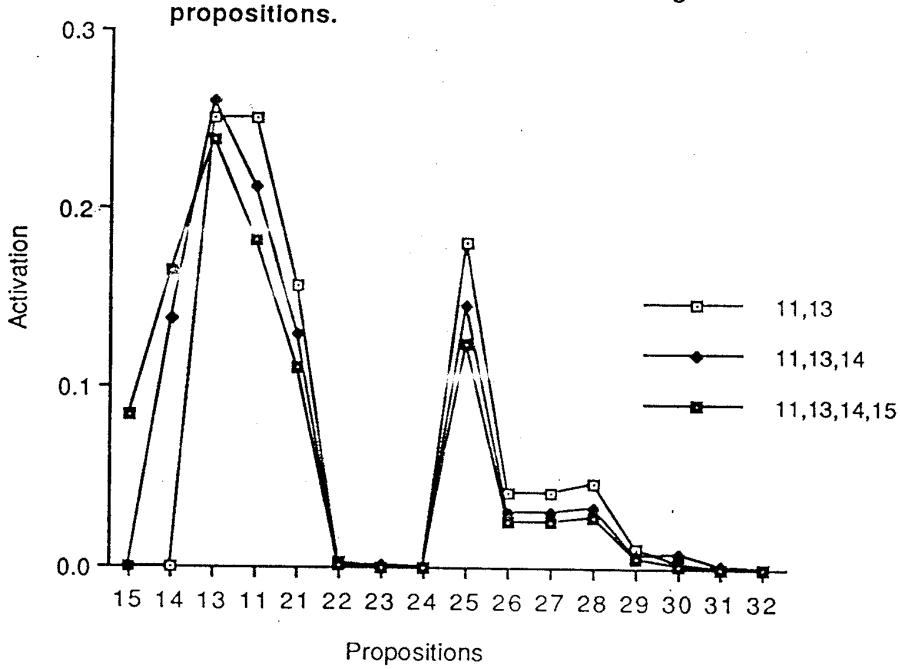
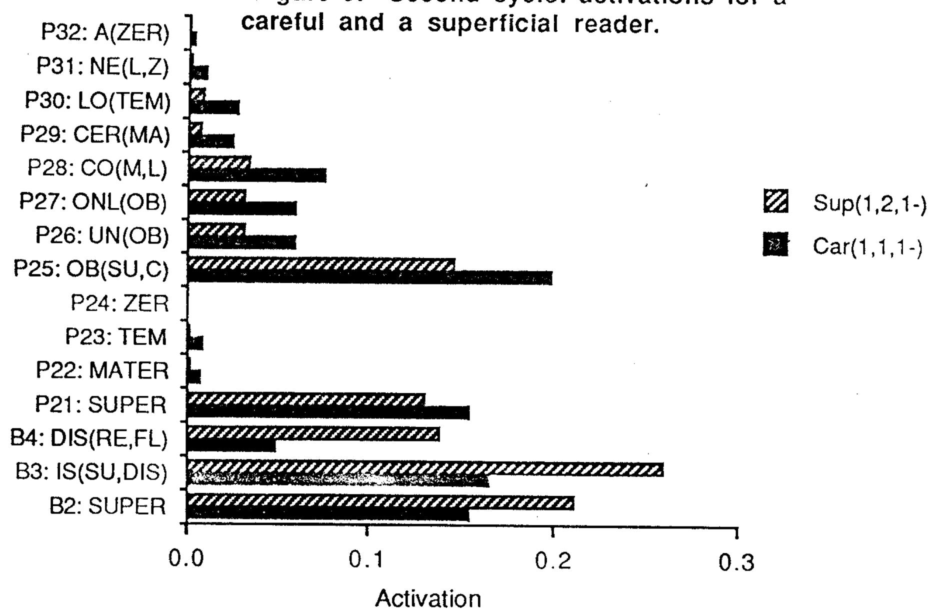


Figure 9. Second cycle: activations for a careful and a superficial reader.



A relatively objective criteria was used to select biasing propositions (B5, B6, B7) for this type of reader: the three most highly activated propositions in cycle 1, P11 SUPERCONDUCTIVITY, P13 IS (SUP, DIS), P14 DIS (RES), were selected. Figure 10 shows the proposition list and the associative network for this cycle. The results in Figure 11 show that increasing the connection strengths of biasing propositions causes the activation of P64: OBTAIN (SUP, INC) to diminish, although it does not disappear. For that, the connection strengths between biasing propositions would have to be increased considerably more. This type of reader seems to characterize subjects for whom there is a very large difference between the activation of these biasing propositions and the text propositions, which causes them to ignore most of the text. This performance should also be expected in previous cycles.

Superficial readers: Type II

These readers mention that superconductivity is obtained by cooling. Using the same criterion as in the previous section, it is assumed that the biasing propositions for these readers will be the most highly activated propositions for superficial readers in the second cycle: B8 (=P11 =P21): SUPERCONDUCTIVITY, B9 (=P13): IS (SUP, DIS), B10 (=P25): OBTAIN (SUP, COOL). Figure 12 shows the propositional analysis for this case and the associative network. P64: OBTAIN (SUP, INC) and B10: OBTAIN (SUP, COOL), being contradictory, are connected by a negative link. Figure 13 compares the resulting activations of propositions for careful and superficial readers. As in the previous case, increasing the connection strengths of biasing propositions causes the activation of P64 to diminish, but it does not disappear. But it should be noted that its argument P66 INCREASE (TEMPERATURE) disappears completely for connection strengths of 2 units and up. This reader would not

Text: Until now superconductivity was obtained by considerably increasing the temperature of certain materials

Biasing information: Superconductivity is the disappearance of resistance

B5 (P11): SUPERCONDUCTIVITY
B6 (P13): IS (SUPERCONDUCTIVITY, DISAPPEAR)
B7 (P14): DISAPPEAR (RESIST (FLOW))

P61: SUPERCONDUCTIVITY
P62: MATERIALS
P63: TEMPERATURE
P64: OBTAIN (SUP, CONSIDERABLY (INCREASE (TEMPERATURE)))
P65: UNTIL NOW (OBTAIN)
P66: INCREASE (TEMPERATURE)
P67: CONSIDERABLY (INCREASE (TEMPERATURE))
P68: POSSESS (CERTAIN (MATERIALS), TEMPERATURE)
P69: CERTAIN (MATERIALS)

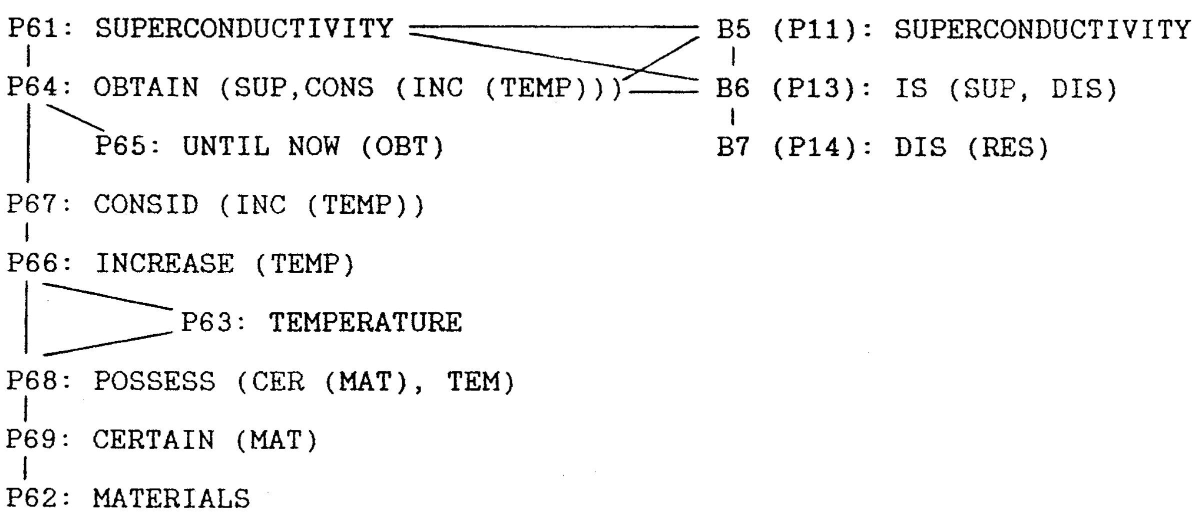
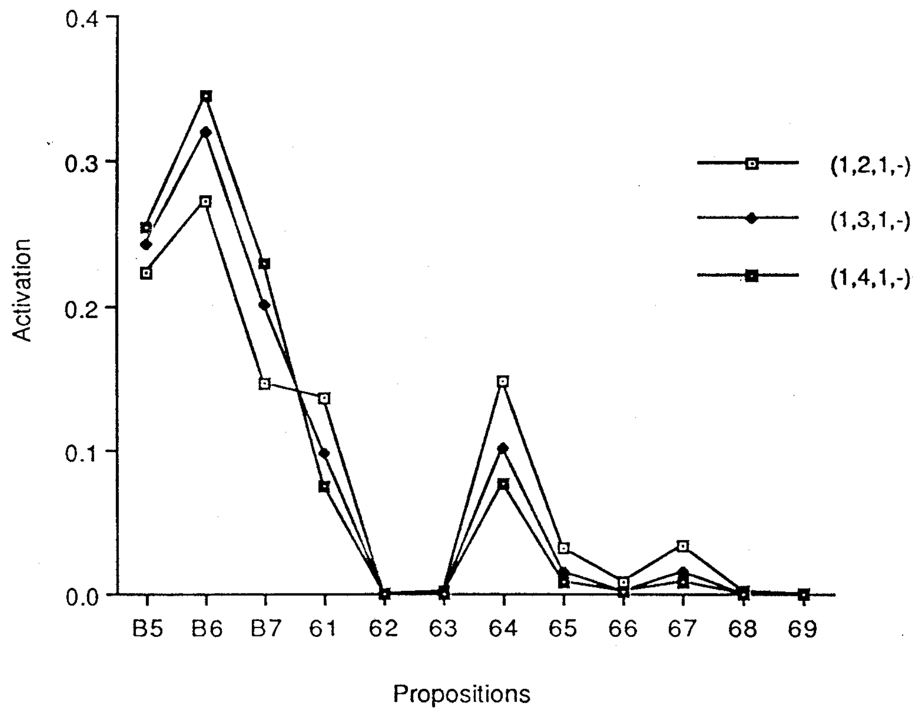


Figure 10. Superficial reader I. Propositional analysis and network for the last cycle.

Figure 11. Superficial reader I: activations for three different connection strengths of the biasing propositions.



Text: Until now superconductivity had been obtained by considerably increasing the temperature of certain materials

Biasing information: Superconductivity is disappearance. Superconductivity is obtained by cooling.

B8 (P11): SUPERCONDUCTIVITY
B9 (P13): IS (SUPERCONDUCTIVITY, DISAPPEAR)
B10 (P25): OBTAIN (SUP, COOL)

P61: SUPERCONDUCTIVITY
P62: MATERIALS
P63: TEMPERATURE
P64: OBTAIN (SUP, CONSIDERABLY (INCREASE (TEMPERATURE)))
P65: UNTIL NOW (OBTAIN)
P66: INCREASE (TEMPERATURE)
P67: CONSIDERABLY (INCREASE (TEMPERATURE))
P68: POSSESS (CERTAIN (MATERIALS), TEMPERATURE)
P69: CERTAIN (MATERIALS)

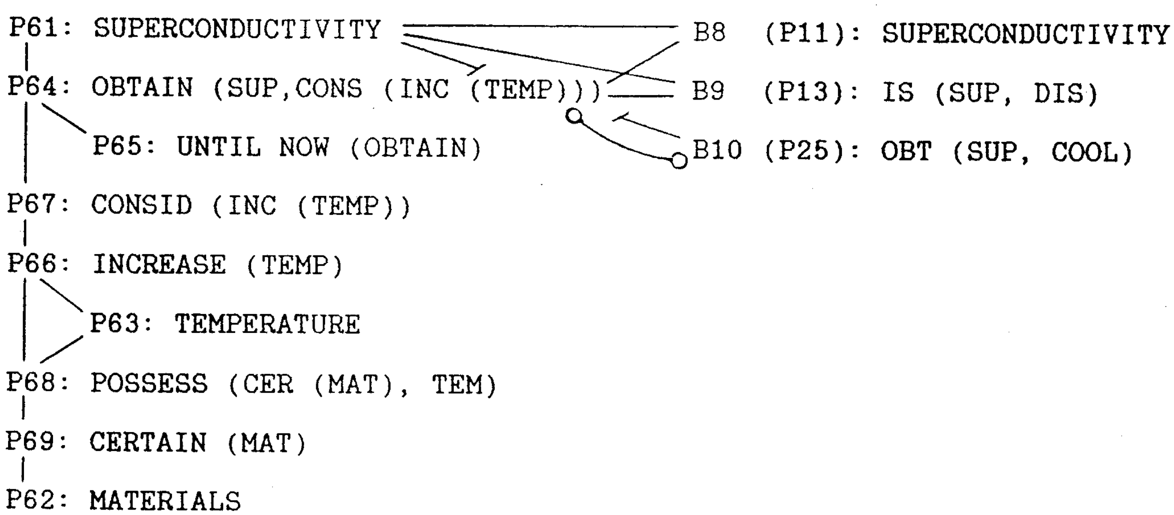
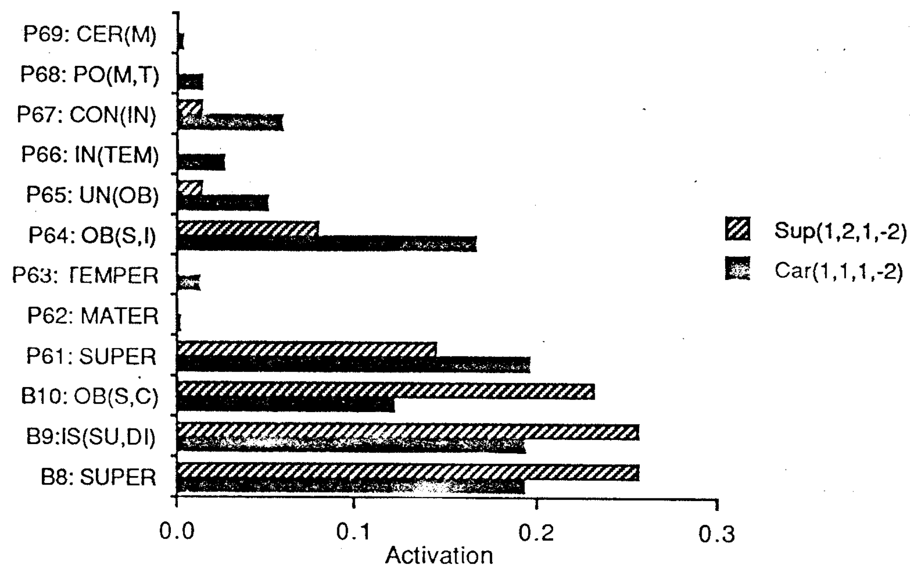


Figure 12. Superficial reader II. Propositional analysis and network for the last cycle

Figure 13. Careful reader and superficial reader II.



notice the contradiction since there is no longer an active proposition contradicting B10.

The supression of one of the contradicting propositions in this cycle has been found to be formally achieved in two different ways: (a) by increasing the connection strength of the biasing propositions, as was just done, or (b) by increasing, above 2, the absolute value of the negative connection strengths between biasing and text propositions. Figure 14 presents the activation of the contradictory propositions in these two cases. As shown there, increasing the absolute value of the negative connection causes the biasing proposition, B10, to disappear while the text proposition, P64, obtains a relatively high activation. But, according to the results in Figure 3 this situation appears unlikely: only five per cent of the nondetectors remembered the second contradictory proposition and not the first. This leads to the conclusion that one of the causes of nondetection among superficial readers is the supression of the contradictory text proposition (the activation of P64 diminishes and its argument P66 completely disappears), due to an increased activation of the biasing proposition P25. This increased activation is reflected in the important percentage of nondetectors who remembered the first contradictory proposition, as shown in Figure 2.

Superficial reader: Type III

For the subjects in this situation, the simulation includes as a biasing information: "Superconductivity is now obtained by new means" (Figure 15). The written protocols suggest that in this case the biasing propositions are retrieved from the general knowledge of the readers, as there are no such propositions in the text. For a superficial reader these biasing propositions should lead to ignoring the time proposition in the last cycle, P65: UNTIL NOW (OBTAIN). This, as shown in Figure 16, is what actually happens. For a careful

Figure 14a. Activations of contradictory propositions depending on the connection strength between biasing propositions.

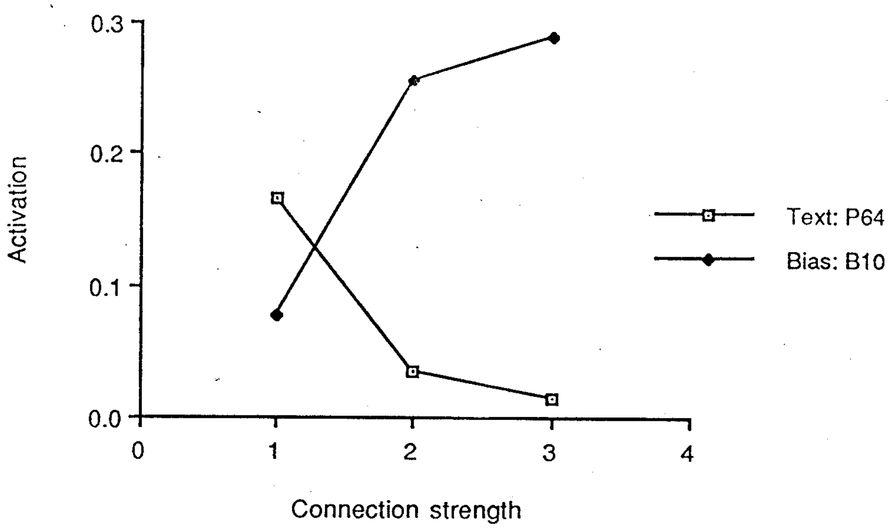
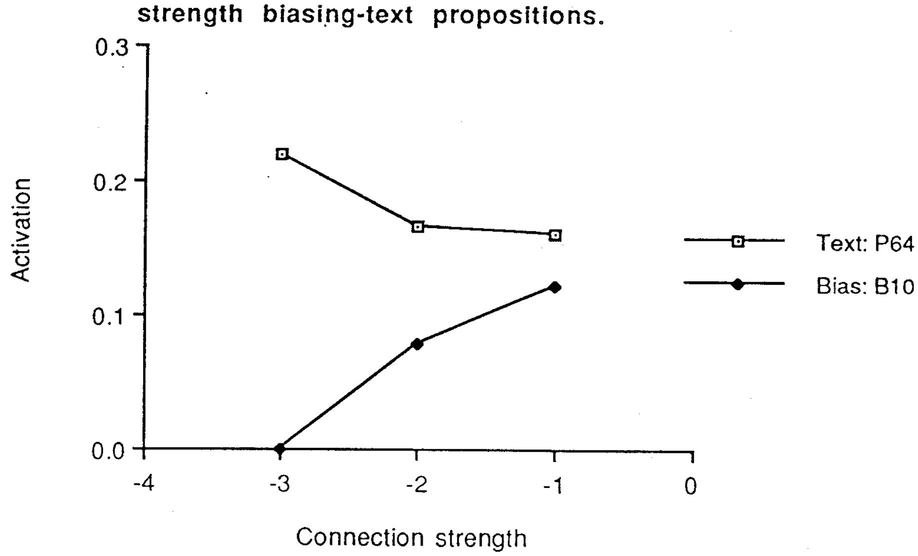


Figure 14b. Activations of contradictory propositions depending on the connection strength biasing-text propositions.



Text: Until now superconductivity had been obtained by considerably increasing the temperature of certain materials.

Biasing information: Superconductivity is now obtained by new means.

B11 (P11): SUPERCONDUCTIVITY
B12 : OBTAIN (SUPERCONDUCTIVITY, NEW (MEANS))
B13 : NOW ON (OBTAIN)

P61: SUPERCONDUCTIVITY
P62: MATERIALS
P63: TEMPERATURE
P64: OBTAIN (SUP, CONSIDERABLY (INCREASE (TEMPERATURE)))
P65: UNTIL NOW (OBTAIN)
P66: INCREASE (TEMPERATURE)
P67: CONSIDERABLY (INCREASE (TEMPERATURE))
P68: POSSESS (CERTAIN (MATERIALS), TEMPERATURE)
P69: CERTAIN (MATERIALS)

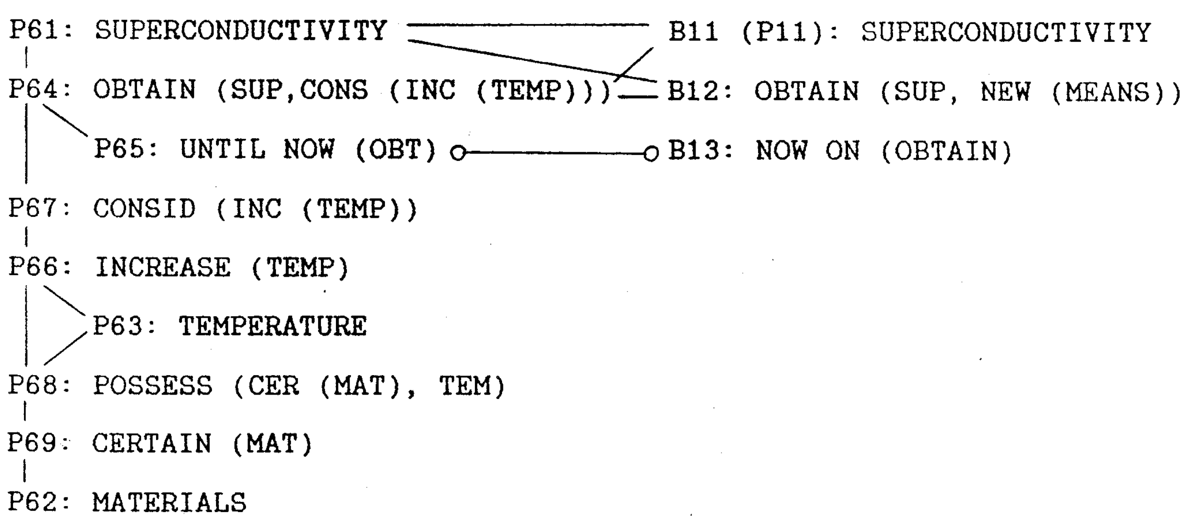
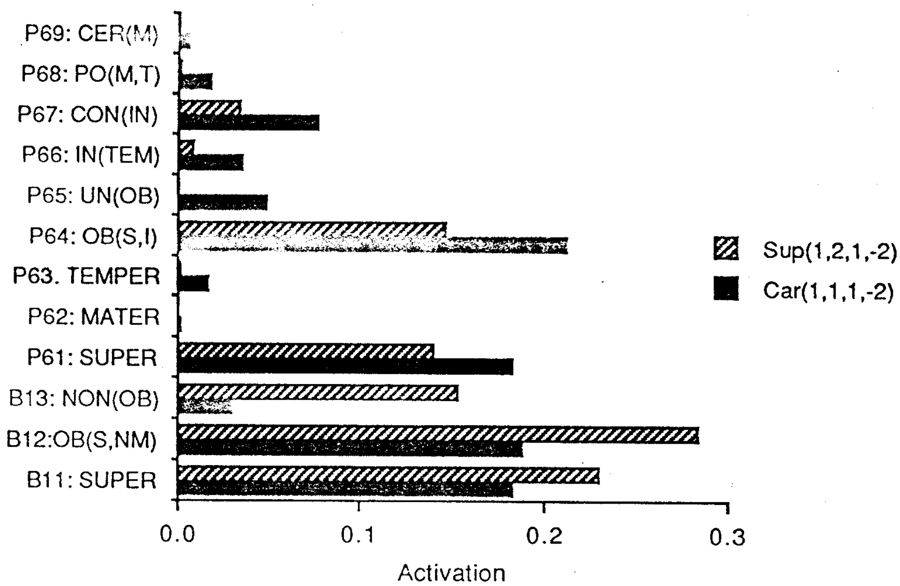


Figure 15. Superficial reader III. Propositional analysis and network for the last cycle.

Figure 16. Careful reader and superficial reader III.



reader, on the other hand, both P65 and the tentative proposition B13: NOW ON (OBTAIN) have a low but nonzero activation. That means that this interpretation would not succeed.

Results similar to these are obtained when the biasing information is made more specific, e.g. "Superconductivity is now obtained by increasing the temperature".

Competing biasing propositions

The following protocol is from a 12th-grade student:

> Superconductivity appears in surfaces which do not have friction. The problem with this is that one needs to lower the temperatures a lot to obtain this state of non-friction. It is very important for industry, but difficult to apply, because of the difficulty of achieving this low temperature (708).

As we have seen, careful readers do not supress propositions in a text that are contradictory to those that they generate by themselves, which allows them to recognize the contradiction. Why, then, are propositions related to friction not activated for careful readers, as has happened for reader 708? The model suggests that the final representation of the text for this reader is explained by a high activation of biasing propositions related to friction--the same mechanism which causes the supression of contradictory propositions under certain macropropositions. This could be the case for a superficial reader who has overlearned the biasing information (friction in this case) or who has had a more recent exposure to it.

This situation is simulated by including as biasing propositions during the first cycle (where superconductivity is defined) the following four propositions, two related to the "friction" interpretation and two related to the "electric" interpretation: B14: RESIST (SLIDING), B15: ON (SLIDING, SURFACE),

B16: ELECTRIC (RESISTANCE), B17: ELECTRIC (CHARGE). Friction and electric propositions are connected by negative links (Figure 17), reflecting the fact that they are incompatible interpretations of the text. Figure 18 shows the final activation of electric and friction propositions as a function of the connection strength of friction propositions. The connection strengths between all the other propositions is kept at a value of 1. As seen from the graph, when 1 is also the connection strength of the friction propositions (a careful reader) the electric interpretation prevails. But if the connection strength between friction propositions is increased above 2.0 (a type of superficial reader), the electric interpretation is suppressed and the reader understands the text as referring to a friction phenomenon.

Parallel constraints

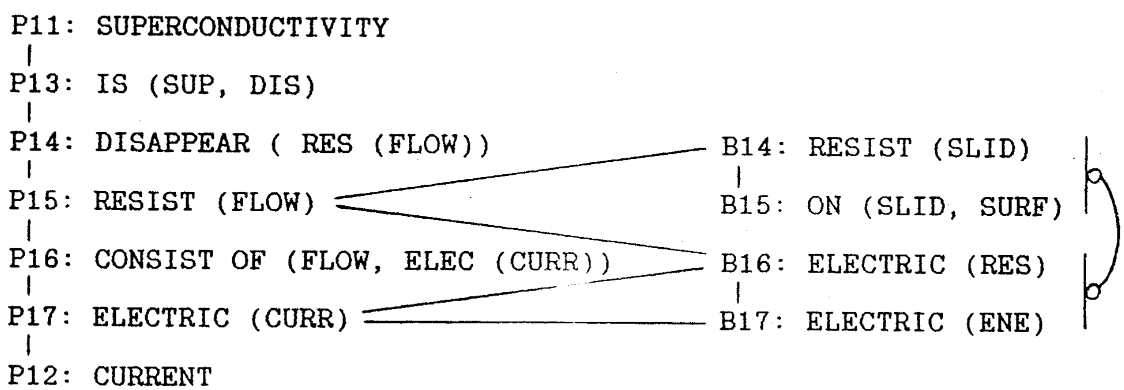
In the simulations described above, biasing propositions were selected as plausible guesses on the basis of the recall data. The purpose was to show that it is possible to account for the observed results, i.e., the overlooking of contradictions by three types of superficial readers. In this section a more complex situation is simulated: the case in which alternative biasing propositions entering the construction phase could restore the coherence of the text. The last contradictory proposition, P64: OBTAIN (SUP,CONS (INC (TEMP))), could trigger two alternative inferences (actually found in the recall protocols) which could restore the coherence of the text: (a) it could refer to a time situation (NOW) different from that of P25 OBTAIN (SUP, COOL)--this is the interpretation apparently made by Type III superficial readers--or (b) it could refer to the same time situation, saying the same thing as P25 (superconductivity is obtained by COOLING). If P66: INC (TEMP) is active, alternative (a) would imply supressing the text proposition P65: UNTIL NOW (OBT). However, if P65: UNTIL NOW (OBT) is active, alternative (b) would

Text: Superconductivity is the disappearance of resistance to the flow of electric current.

Biasing information: Resistance to sliding on a surface. Electric resistance. Electric energy.

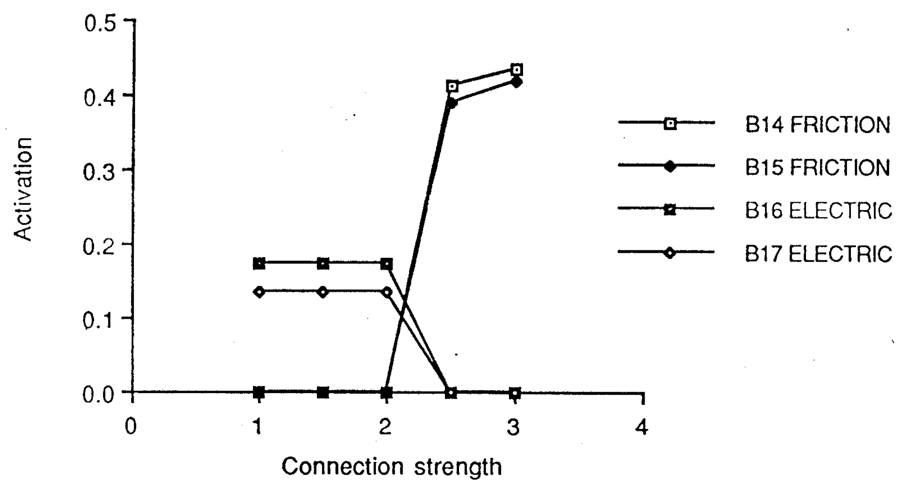
B14: RESIST (SLIDING)
B15: ON (SLIDING, SURFACE)
B16: ELECTRIC (RESISTANCE)
B17: ELECTRIC (ENERGY)

P11: SUPERCONDUCTIVITY
P12: CURRENT
P13: IS (SUPERCONDUCTIVITY, DISAPPEAR (RESIST (FLOW)))
P14: DISAPPEAR (RESIST (FLOW))
P15: RESIST (FLOW)
P16: CONSIST OF (FLOW, ELECTRIC (CURRENT))
P17: ELECTRIC (CURRENT)



<u>Figure 17</u>. Competing biasing propositions. Propositional analysis and network for the first cycle.

Figure 18. Activation of biasing competing propositions as a function of the connection strength between friction propositions.



imply supressing P66: INCREASE (TEMPERATURE). B19: UNTIL NOW (OBT (SUP, COOL)) of alternative (b), is also incompatible with P65: UNTIL NOW (OBT (SUP, CONS (INC))) but only in case that they refer to contradicting methods of obtaining superconductivity, that is, if P66: INC (TEMP) is active. These possible situations are portrayed in Figure 19. Two biasing propositions, connected by an inhibitory link, compete with each other: B18: NOW (OBTAIN (SUP, INC)) or B19: UNTIL NOW (OBTAIN (SUP,COOL)). In this case there are no fixed negative connections between biasing and text propositions because the incompatibility of B18 and P65 depends on whether P66 is active or not; the incompatibility of B19 and P66 and B19 and P65 depends on whether P65 and P66, respectively, are active or not. This is implemented in the model by using the simple linear function shown in Figure 19 to obtain variable connection strengths which will change with every iteration. For example, if at some particular point during the integration process, P66 is active with a value of .3, B19 and P65 would be incompatible, and the connection strength between them would be -2. In case P66 disappears, B19 and P65 would be compatible and the connection strength between them would be 1.

Figures 20 and 21 show, for careful and superficial readers respectively, the activation of the four target propositions as the integration process proceeds. Careful readers are simulated as usual. Superficial readers are simulated by increasing the connection strengths B18-B18 and B19-B19 to 4 units. The activation values for B18 and B19 in the initial vector are set to zero, both for careful and superficial readers. After the integration process, careful readers do not supress the time proposition P65: UNTIL NOW, although its activation is low. Thus, it would be possible to recognize the contradiction between B18 and P65. B19, the second tentative interpretation disappears. For a superficial reader, on the other hand, P65 is completely supressed, B18

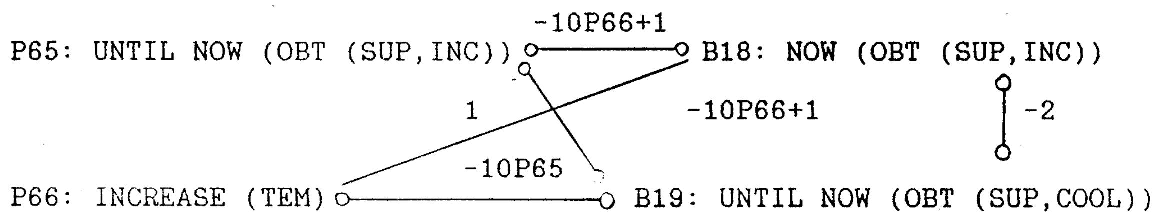


Figure 19. Variable connections for the alternative interpretations in the last cycle.

Figure 20. Careful reader: changes in activation during the integration phase of propositions linked by variable connections

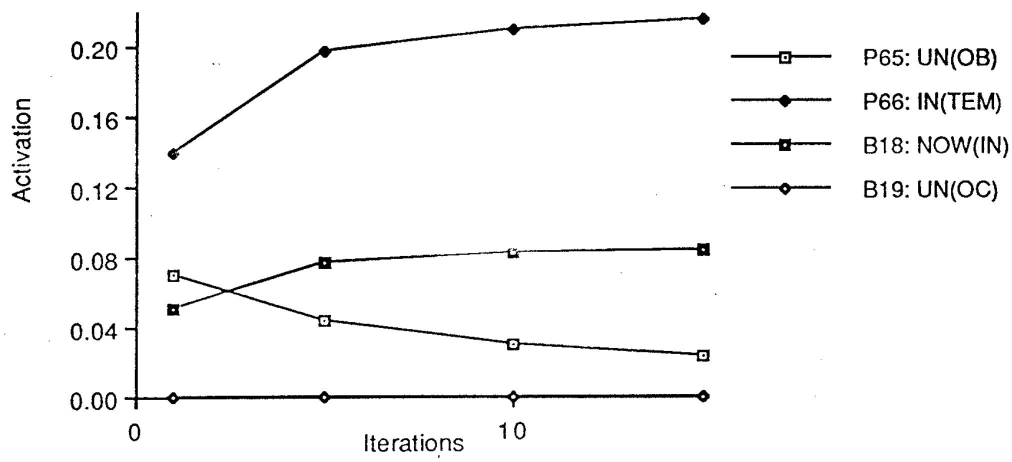


Figure 21. Superficial reader: changes in activation during the integration phase of propositions linked by variable connections

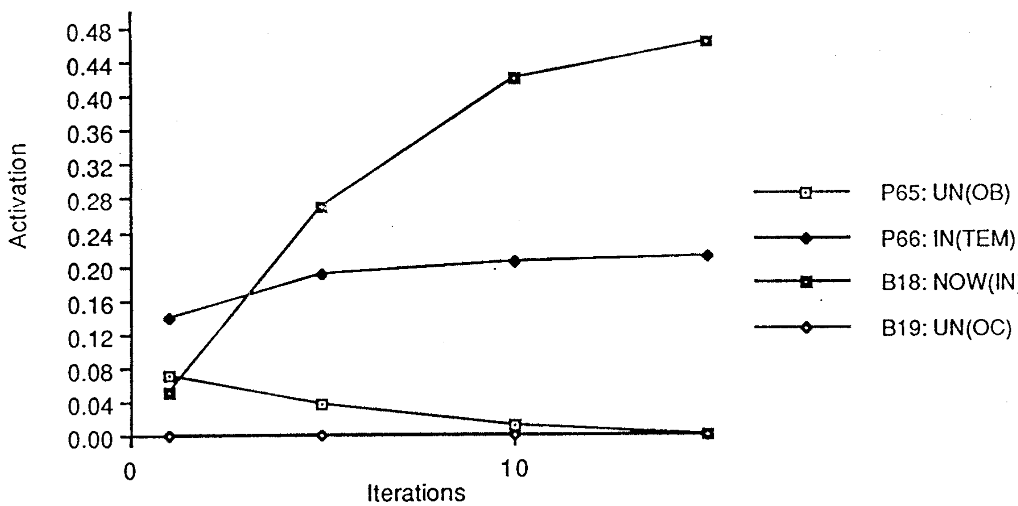
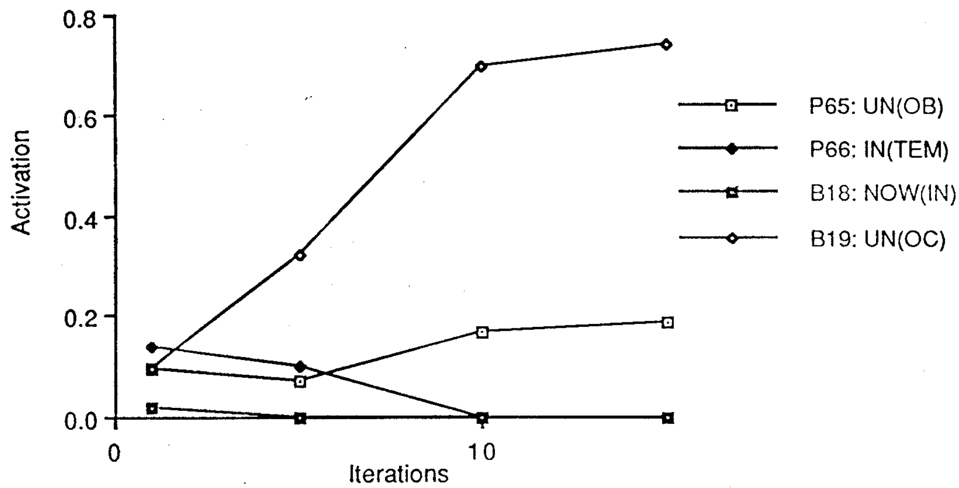


Figure 22. Superficial reader (B19-B19=5): changes in activation during the integration phase of propositions linked by variable connections.



obtains a very high activation, and the situation would be like that of Type III superficial readers, illustrated by the protocol of subject n. 806 in page 9.

How would one model the results exemplified by Type II superficial readers, those who believe that "Superconductivity is obtained by cooling"? Figure 22 shows the results of the simulation when the activation of B19 is very high. Setting the connection strength B19-B19 to 5 units, while keeping that of B18-B18 at 1, produces alternative (b), mentioned above: B19: UNTIL NOW (OBTAIN (SUP, COOL)) attains a very high activation, and the time proposition P65 in the text does not disappear. On the other hand, P66: INCREASE (TEMP), being contradictory to B19, disappears from the final representation together with B18.

The "Moses illusion"

One well documented instance of failure to monitor comprehension is the so called "Moses illusion" (Erickson and Matson, 81). Subjects were asked "How many animals of each kind did Moses take on the ark?". Seventy three percent of the subjects in this study did not notice the inconsistent name, even though they possessed the correct knowledge. The effect is also obtained when the question is changed into a statement, and the subjects are asked to check its validity. The processes which have been examined above should also explain this phenomenon.

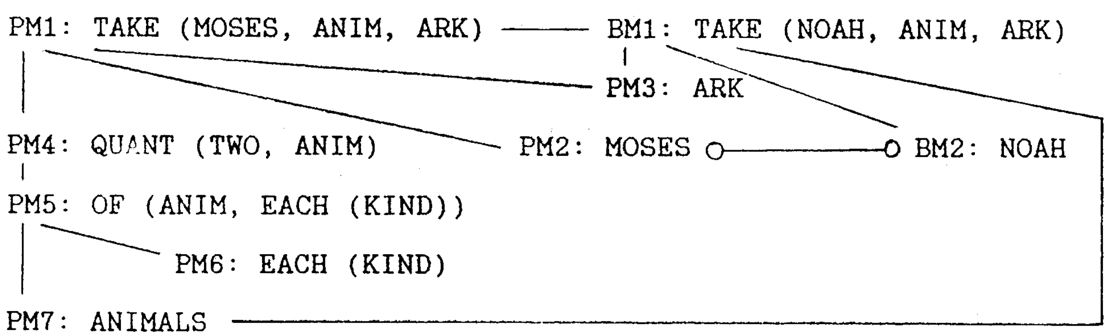
A simulation was performed assuming that processing is biased by two general knowledge propositions retrieved from long term memory: BM1: TAKE (NOAH, ANIMALS, ARK) and BM2: NOAH. The associative network is shown in Figure 23. PM2: MOSES and BM2: NOAH, although not linked by argument overlap, are connected because they share some semantic features (both are biblical names, for example). This link will play an important role in the second part of the simulation, below. They are initially connected by a

Text: Moses took two animals of each kind on the Ark.

Biasing information: Noah took animals on the Ark.

BM1: TAKE (NOAH, ANIMALS, ARK)
BM2: NOAH

PM1: TAKE (MOSES, ANIMALS, ARK)
PM2: MOSES
PM3: ARK
PM4: QUANT(TWO, ANIMALS)
PM5: OF (ANIMALS, EACH (KIND))
PM6: EACH (KIND)
PM7: ANIMALS



<u>Figure 23</u>. Propositional analysis and associative network for the Moses text.

Figure 24. Activation of propositions in the Moses text for a careful reader, a superficial reader and a reader for whom PM2 is especially active.

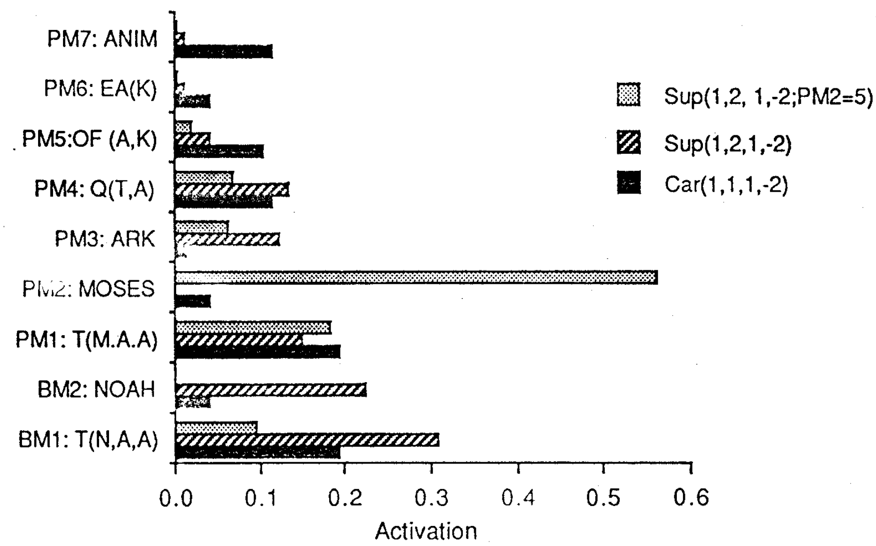


Figure 25a. Activation of PM2 and BM2 as a function of the connection strength between both propositions (symmetric connection).

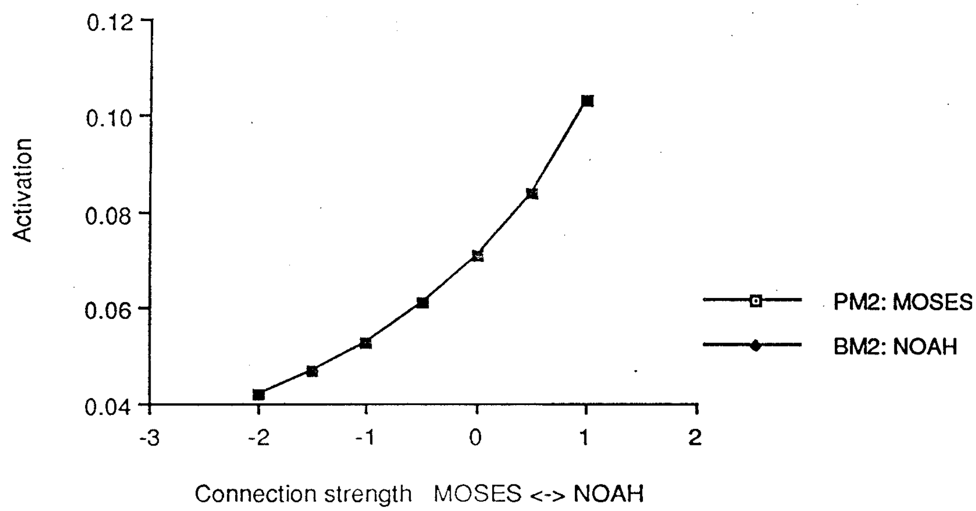
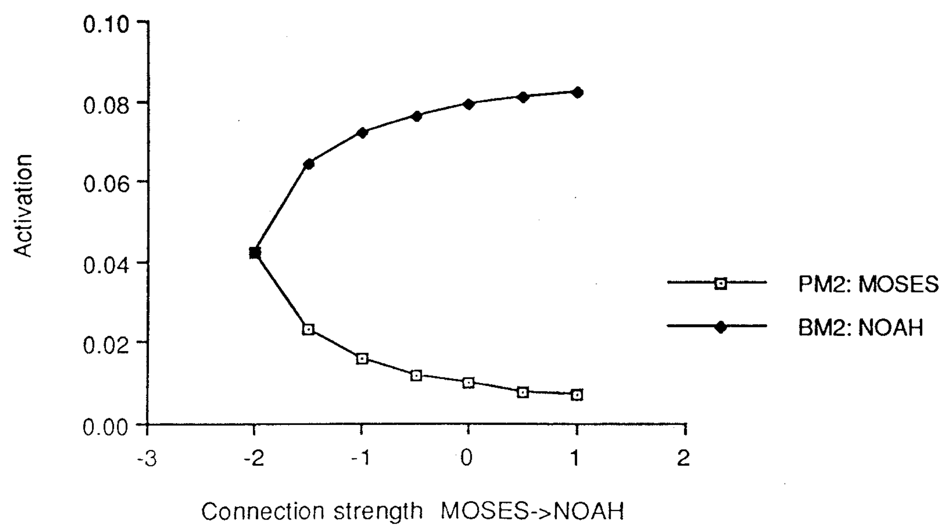


Figure 25b. Activation of PM2 an BM2 as a function of the connection strength between both propositions (asymmetric connection).



negative weight, reflecting the fact that they are incompatible arguments of the proposition TAKE (X, ANIMALS, ARK).

Figure 24 shows the resulting activation in three situations. First, for a careful reader, both PM2: MOSES and BM2: NOAH obtain a relatively low, but similar activation. For a superficial reader PM2: MOSES disappears, while the biasing proposition BM2: NOAH gets a much higher activation. The subject in this case would not notice the incoherence. The last situation corresponds to the case in which the inconsistent name is semantically very rich (if Gorbachev, for example, were used instead of Moses), or if it were stressed in some way (for example by saying it in louder voice or printing it in bold letters). It is simulated here by increasing the connection strength PM2-PM2 up to 5. As seen from the graph, the inconsistent name does not disappear in the final text representation, as expected.

One of the results obtained by Erickson and Matson concerns the importance of the semantic similarity between the names in order to obtain the illusion. The more similarity between the inconsistent name and NOAH, the easier it is for the former to disappear in the final representation. Semantic similarity of the two names can be manipulated in the model by varying the connection strength between them. It should be expected that the higher this value is (the more semantically similar), the lower the activation of the false name and the higher the activation of BM2: NOAH should be. Figure 25a shows the activation of PM2: MOSES and BM2: NOAH as a function of the connection strength between them. Both the activation of BM2: NOAH and PM2: MOSES <u>increase</u> with the increase in semantic similarity, contrary to the observations. This situation suggests that there could be an asymmetrical flow of activation between propositions: the greater the activation flow between the inconsistent name and BM2: NOAH (i.e., the greater the semantic similarity) the greater the inhibiting influence from BM2: NOAH to the inconsistent name. This situation can be implemented by using greater connection strengths from the biasing proposition to the text proposition than in the opposite direction, that is, using an asymmetrical connectivity matrix. Figure 25b shows the activation values for PM2: MOSES and BM2: NOAH as a function of the connection strength PM2: MOSES-->BM2: NOAH. The connection strength BM2-->PM2 is kept constant at -2. In this case an increase in semantic similarity, that is of activation flow from PM2 to BM2, has the expected result: the activation of PM2: MOSES decreases while that of BM2: NOAH increases.

This simulation suggests an additional mechanism which could also explain cases of nondetection of contradictions. There may be some readers for whom the activation mainly flows in the direction from biasing propositions to text propositions, with little influence of text propositions on biasing propositions.

4. Conclusions

A simulation mechanism was presented to explain how contradictions are overlooked in comprehending manipulated texts, a phenomenon which until now has been studied in a descriptive manner. A high activation of certain biasing propositions entering the construction phase of the C-I model explains the distortions in the final representation of contradictory texts, i.e. the fact that some text propositions completely disappear. These biasing propositions could be macropropositions which are generated by the reader from the text or retrieved from the general knowledge store, or they may be micropropositions which for some reason are especially active. This mechanism provides an operational characterization of various kinds of top-down readers which lends itself easily to empirical test. For a network containing propositions connected through inhibitory links, differential preliminary activation of key propositions in a reader's memory should influence the final representation of the incompatible propositions. This explanatory hypothesis could open new possibilities for exploring the role of especially weighted knowledge in the processing of information. The influence of beliefs and values in the area of social psychology or that of preconceptions in the learning of science and mathematics are examples of phenomena where this approach could be of some utility.

5.References

Baker, L. (1979). Comprehension monitoring: Identifying and coping with text confusions. Journal of Reading Behavior, 11, 365-374.

Baker, L. (1985a). Differences in the standards used by college students to evaluate their comprehension of expository prose. Reading Research Quarterly, 20, 297-313.

Baker, L. (1985b). How do we know when we don't understand? Standards for evaluating text comprehension. In D.L. Forrest-Pressley, G.E. Mackinnon, T.G. Waller (Eds.), Metacognition, cognition and human performance. New York: Academic Press.

Baker L., Anderson R.I. (1982). Effects of inconsistent information on text processing: Evidence for comprehension monitoring. Reading Research Quarterly, XVII, 281-294.

Campanario, J.M., Otero, J. (1989). Comprehension monitoring abilities of secondary school students reading science texts: a cluster analysis. Unpublished manuscript, Departamento de Fisica, Universidad de Alcala, Madrid.

Erickson, T.D., Mattson, M.E. (1981). From Words to Meaning: A Semantic Illusion. Journal of Verbal Learning and Verbal Behavior, 20, 540-551.

Glenberg A.M., Wilkinson A.C., Epstein, W. (1982). The illusion of knowing: Failure in the self-assessment of comprehension. Memory & Cognition, 10, 597-602.

Kintsch. W. (1974). The representation of meaning in memory. Hillsdale, N.J.: Erlbaum.

Kintsch, W. (1988). The Role of Knowledge in Discourse Comprehension: A Construction-Integration Model. Psychological Review, 95, 163-182.

Kintsch, W., van Dijk, T.A. (1978). Toward a model of text comprehension and production., Psychological Review, 85, 363-394.

Kintsch, W. & Welsch, D. (in press). The construction-integration model: A framework for studying memory for text. In W.E. Hockley & S. Lewandowsky (Ed.) Relating theory and data: Essays on human memory. Hillsdale, N.J.: Erlbaum.

Mannes, S., Kintsch, W. (1989). Planning Routine Computing Tasks: Understanding What to Do (ICS Technical Report 89-8). Boulder, Co: Institute of Cognitive Science, University of Colorado.

Markman, E.M. (1979). Realizing that you don't understand: Elementary School children's awareness of inconsistencies. Child Development, 50, 643-655.

Markman, E.M., Gorin, L. (1981). Children's ability to adjust their standards for evaluating comprehension. Journal of Educational Psychology, 73, 320-325.

Otero, J., Campanario, J.M. (1990).Comprehension evaluation and regulation in learning from science texts. Journal of Research in Science Teaching, 27, 447-460.

Van Dijk T.A., Kintsch, W. (1983). Strategies of Discourse Comprehension. New York: Academic Press.

Vosniadou, S.P., Pearson, D.P., Rogers, T. (1988). What Causes Childrens' Failures to Detect Inconsistencies in Text? Representation Versus Comparison Difficulties. Journal of Educational Psychology, 80, 27-39.