Sonderdruck aus der
ZEITSCHRIFT FÜR PSYCHOLOGIE
Band 186, Heft 1 (1978)
JOHANN AMBROSIUS BARTH, VERLAG, LEIPZIG
Printed in the German Democratic Republic

From the Central Institute for Cybernetics and Information Processing of the Academy of Sciences of the GDR, Berlin

Solving problems about incomplete relational structures

By R. BLUTNER

With 2 figures

A widely unsolved problem in problem solving research concerns the mechanisms which lead to the task comprehension. It has been assumed that the generation of an internal representation, based on the linguistic information input from the task, possesses a key position in task comprehension. Therefore the main question in this research field concerns the nature of this internal representation.

Two alternative conceptions of language processing have been suggested by those who have speculated about the nature of comprehension in problem solving processes. The first, and perhaps the dominant, conception has assumed that a parsing of each sentence in an input text takes place, resulting in a semantic interpretation of the text [1]. Such interpretative models of discourse processing have most often been suggested by researchers borrowing heavily from computational linguistics and the transformational tradition in linguistics. The second conception may be called the constructivist conception. In this conception, the comprehension-memory system does not semantically process each input sentence; rather, it selectively processes the input, using information selected from the current input to generate an integrated situational structure which 'fits' the input 'data' [2, 3].

Recent research in language comprehension has tried to support the constructivist theory of comprehension. The BRANSFORD and FRANKS group has devised numerous experiments to demonstrate the validity of this approach. However some of their findings, e. g. that the two sentences "Three turtles rested on a floating log and a fish swam beneath them/it" are confused in recognition, can be interpreted in a modified interpretative framework too, if it is assumed that subjects make deductive inferences while studying input sentences and that these inferences are stored along with the information which was actually presented [1]. POTTS [4] has attempted to model the abstract constructive encoding process and to describe what is stored for at least one type of meaningful verbal material. POTTS employed English paragraphs describing the pairwise relation between n terms ($n=4, 5, 6$). Using in the acquisition phase complete paragraphs, like "a is greater than b, b is greater than c, c is greater than d" describing who is greater than who for all elements of (a, b, c, d), POTTS has consistently found that subjects in answering test questions concerning this total order of elements perform better on remote pairs (e. g. $b>d$) than on adjacent pairs (e. g. $b>c$), even if the remote

pairs are not presented during the acquisition phase. This strongly contradicts each kind of interpretative conceptions. In our experiments we are interested in incomplete paragraphs (partial orderings) like "a is greater than c, b is greater than c, c is greater than d" leaving undecided for some elements of (a, b, c, d) who is greater than who. Such incomplete relational structures are of interest for at least two reasons:

– The demonstration that incomplete information about orderings is completed during the encoding process would be a further convincing argument supporting the constructivist conception and paralysing the upper objection.
– Incomplete relational structures permit the identification of internal structures not identifiable using complete relational structures. However they may appear there during the encoding process.

The results presented here concern the first statement only.

Method

Subjects were 12 postgraduates. Each participated in one 40-minute session. We have designed a set of five tasks and one practice task, each of these corresponding to a special partial ordering.

Our procedure is schematiced in figure 1. Let's consider the first task. The training consisted of first showing the subject one of six type-written questions, for example. "Is a greater than c?", recording his choice ("yes"/"no") and than giving him feedback. Small letters stand for one-syllable male names. The six training questions were presented in a blocked randomized order. The blocks were repeated until the subject met a criterion of two successively correct trialblocks. Then he was tested without feedback on all possible pairs. Subjects were instructed to do two different things in testing:

– to answer the current test question with "yes" or "no" or "uncertain"
– to decide whether the current question was old or new.

The test questions are summarized as a matrix in the right-hand side of figure 1. The pairs marked with T correspond to the training questions. The I-pairs correspond to questions whose answers follow by deductive inference from the training information. The U-pairs correspond to questions where the incompleteness of training information makes the answer undecidable.

After performing the first task subjects turned to the next. The order of tasks was permutated for subjects.

Results and discussion

Two types of results are presented in this paper only. Firstly, it has been shown that semantic consistent internal structures are acquired in case of partial orderings. Secondly, it could be demonstrated that partial orderings are completed during the encoding process.

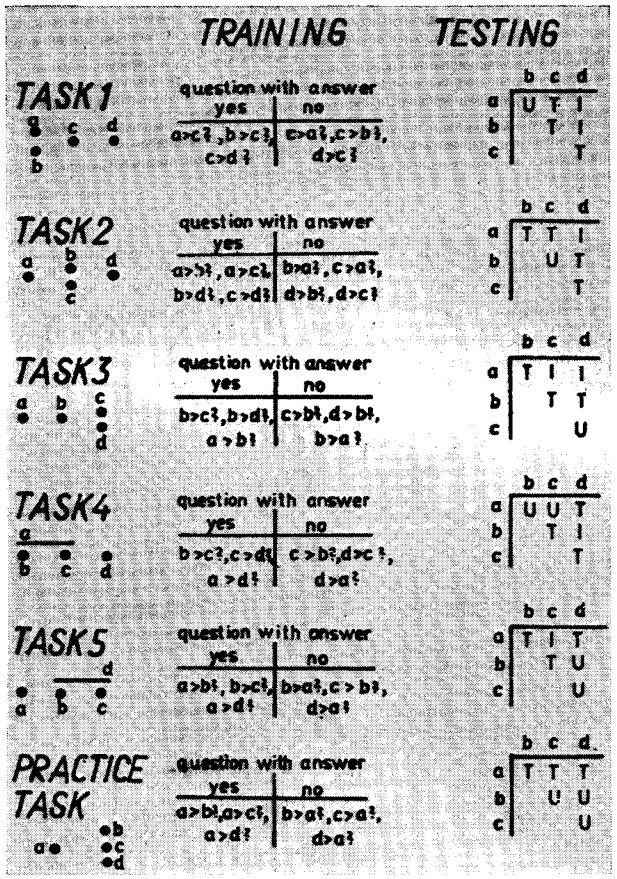

Fig. 1. Schematic outline of training and testing for incomplete four-term series problems

Semantic consistency

The answer to a question "Is x greater than y" in the test phase is called semantic inconsistent if

a) (for T-questions) the answer is not the same like feedback in training
b) (for-I-questions) the answer is not in agreement with logical consequences from training information (including the answer "uncertain")
c) (for U-questions) internal contradictions appear, e. g., for $a>b$? the answer is "yes" and for $b>a$? the answer is "yes"/"uncertain".

We have found that only 2.1% of T-questions, 2.4% of I-questions and 3.5% of U-questions were answered inconsistently. There are no significant differences between this frequencies ($\alpha = 10\%$). These results show that in our experiments stable internal structures were developed leading to highly semantic consistent answers for each of the three question types.

Completion of relational structures and recognition errors

The main interest of our experiment concerns the investigation of answers to U-questions. Figure 2a presents the percentage of "uncertain"-answers to U-questions for the five different tasks. Averaged over tasks only 30% of those

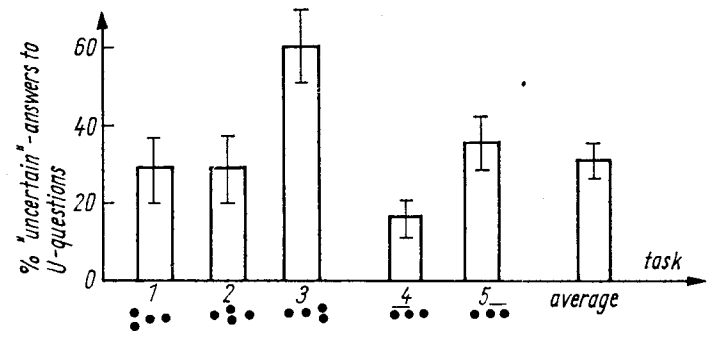

Fig. 2a. Percentage of "uncertain"-answers to U-questions

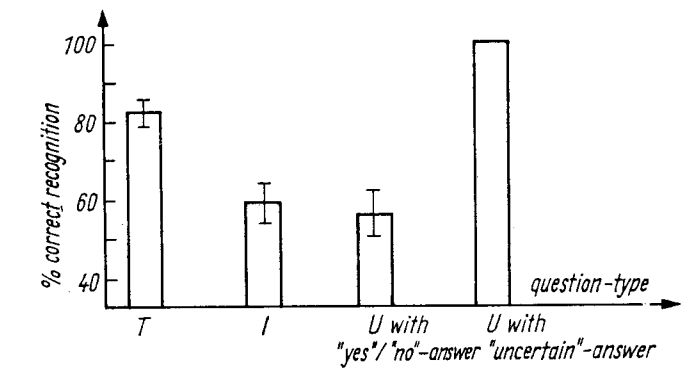

Fig. 2b. Percentage of correct recognition

questions that should be answered as "uncertain" according to formal logic were answered in fact as "uncertain".

Until now it is unclear whether the 70% "yes"/"no"-answers result from completed holistic situational structures or reflect simply the product of some kind of probabilistic inference rules infering a "yes"/"no"-answer from incompleted internal structures. For a decision we use the recognition data from all I-questions and the 70% of U-questions answered by "yes"/"no". With respect to the first hypothesis the percentage of correct recognition should be the same for I-questions and U-questions. The second hypothesis predicts a higher correct percentage for U-questions than for I-questions.

The results presented in figure 2b clearly favour the first alternative – the construction of completed internal structures. Therefore our results confirm an impor-

tant proposition of the constructive memory orientation: the generated internal situational structures embody more information than was available from language input and deductive inferences about it, i. e. the set of all propositions about pairs derivable from the language input is a (proper) subset of the set of all propositions about pairs derivable from the internal structure.

Summary

Numerous experiments conducted by various authors on the model of investigations reported by Bransford et al. have confirmed the view that a coherent text is retained not in accordance with the semantic representation of individual sentences, but that single sentences serve as a starting point for the development in the mind of an integral situational description.

The present paper discusses the development of internal memorial structures for simple texts (paragraphs) describing order designations between n terms. A paragraph such as "Klaus is taller than Fritz, Fritz is taller than Ernst, Ernst is taller than Paul", which describes the total order of the four terms, is referred to a complete. On the other hand, a paragraph such as "Rolf is taller than Fred, Fred, is taller than Hans, Fred is taller than Karl" is called incomplete because the relation between Hans and Karl remains open. The results of this work show effects of integration also for incomplete paragraphs. The internal representations effect the integration of more propositional information than is deductively obtainable from the sentences presented.

Zusammenfassung

Angeregt durch Arbeiten von Bransford u. a. wurde in zahlreichen Experimenten verschiedener Autoren die Auffassung bekräftigt, daß ein zusammenhängender Text nicht entsprechend der semantischen Repräsentation der einzelnen Sätze behalten wird, sondern daß die einzelnen Sätze als Ausgangspunkt für den Aufbau einer integrierenden Situationsbeschreibung im Gedächtnis dienen.

Die vorliegende Arbeit untersucht den Aufbau interner Gedächtnisstrukturen für einfache Texte (Paragraphen), die Ordnungsbeziehungen zwischen n Termen beschreiben. Ein Paragraph wie „Klaus ist größer als Fritz, Fritz ist größer als Ernst, Ernst ist größer als Paul", der die totale Ordnung der vier Terme beschreibt, heißt vollständig. Dagegen ist ein Paragraph wie „Rolf ist größer als Fred, Fred ist größer als Hans, Fred ist größer als Karl" unvollständig, da die Relation zwischen Hans und Karl offen bleibt.

Unsere Arbeit weist Integrationseffekte auch für unvollständige Paragraphen nach. Die aufgebauten internen Repräsentationen integrieren zum Teil mehr propositionale Information als aus den dargebotenen Eingabesätzen deduktiv erschließbar ist.

Резюме

Следуя исследованиям Bransford и др. разные авторы в многочисленных экспериментах подтвердили мнение, что связанный текст не заполняется соответственно семантической репрезентации отдельных предложений, а что отдельные предложения наоборот служат исходным пунктом для построения интегрирующего описания ситуации в памяти. Настоящая работа исследует построение внутренних мнемических структур для простых текстов (параграфов), описывающих порядковые названия между n термами. Параграф «Клаус выше, чем Фритц, Фритц выше, чем Эрнст, Эрнст выше, чем Пауль», описывающий упорядочение четырех термов, называется полным, а параграф «Рольф выше, чем Фред, Фред выше, чем Ганс, Фред выше, чем Карл» – неполным, так как отношение между Ганс и Карл остается открытым.

Наше исследование также доказывает существование эффектов интегрирования для неполных параграфов. Построенные внутренние репрезентации частью интегрируют больше пропозициональной информации, чем это дедуцируется из предъявленных входящих предложений.

References

1. Anderson, J. R., and G. H. Bower: Human associative memory. New York 1973.
2. Bartlett, F. C.: Remembering, Cambridge 1932.
3. Bransford, J. D., R. J. Barclay and J. J. Franks: Cognitive Psychol. *3* (1972) 193–208.
4. Potts, G. R.: J. exper. Psychol. *103* (1974) 431–439.

Author's address:
R. Blutner
Zentralinstitut für Kybernetik und Informationsprozesse
der Akademie der Wissenschaften der DDR
DDR – 1199 Berlin, Rudower Chaussee 5