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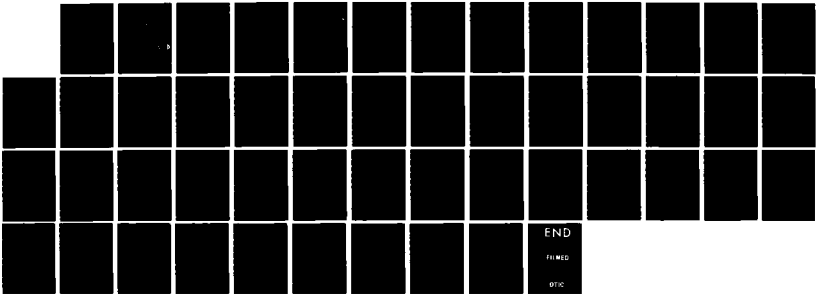

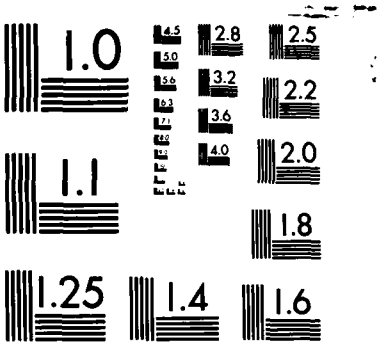

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RULES FOR COMPREHENSIBLE TECHNICAL PROSE:

A SURVEY OF THE PSYCHOLINGUISTIC LITERATURE

David E. Kieras & Christiane Dechert

University of Michigan

Technical Report No. 21 (TR-85/ONR-21)

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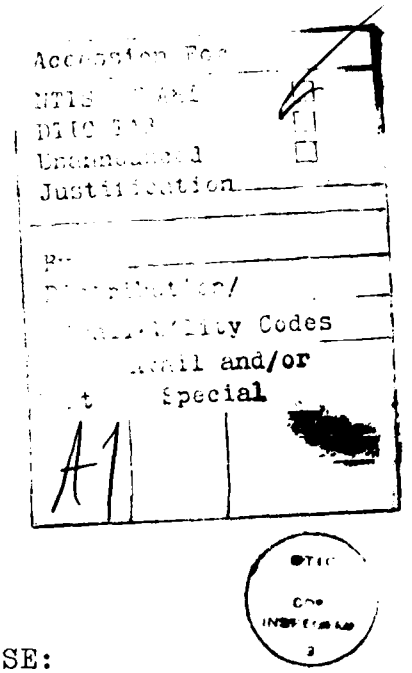
and the rules was that the rules should be applicable by an automatic system without needing deep knowledge of the domain. Rather, the rules should address the surface structure of sentences and text, and the semantic content at a "shallow" level, defined in terms of the propositional representation for the text content. Many rules for good sentence syntax, coherence, text organization, and amount of content are proposed and justified by the experimental literature. The major gaps in the empirical literature are described in a concluding section.



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ABSTRACT

Computerized systems that provide feedback on the comprehensibility of technical prose should be based on what is known scientifically about what makes prose difficult to understand. The experimental psycholinguistics literature was surveyed, and a set of rules for comprehensible technical prose was derived. The basic criteria for selection of the literature and the rules was that the rules should be applicable by an automatic system without needing deep knowledge of the domain. Rather, the rules should address the surface structure of sentences and text, and the semantic content at a "shallow" level, defined in terms of the propositional representation for the text content. Many rules for good sentence syntax, coherence, text organization, and amount of content are proposed and justified by the experimental literature. The major gaps in the empirical literature are described in a concluding section.

RULES FOR COMPREHENSIBLE TECHNICAL PROSE: A SURVEY OF THE PSYCHOLINGUISTIC LITERATURE

David Kieras and Christiane Dechert

This report presents a set of rules for comprehensible writing that is based on a survey of the psycholinguistics literature. Developing these rules is part of a project to develop a computerized system that would evaluate technical prose and identify for the writer the places in the text that will present comprehension problems to the reader (Kieras, 1985a). A key concept in the development of this system is to base its rules for identifying comprehensibility problems on results from the experimental literature in psycholinguistics. Thus this survey was undertaken to identify some rules for comprehensible writing.

This survey covers only certain aspects of the psycholinguistics literature, and deals only with the type of rules that would be useful in a computerized system of the sort proposed in Kieras (1985a). Such rules would govern what comprehensible writing should look like in terms of its form and immediate content, but not its deep underlying content. That is, it is currently well beyond the reach of a practical system to have it examine technical prose in terms of its deep semantic content. For example, one could imagine a system that would examine the maintenance manual for a radar set and make judgments about whether the appropriate content had been included. However, such a system would need to have knowledge of how radar sets work, and would also have to incorporate as yet unknown knowledge about what aspects of radar systems should be in a manual.

In contrast, consider a system that would decide whether a manual had been written clearly with regard to certain important, but relatively simple, aspects of comprehension. As a simple example, consider that inconsistent terminology would be a serious obstacle to comprehension; but it does not necessarily take a large knowledge base to identify when terminology is inconsistent. In fact, one characteristic of clear technical writing is that it should not require an extensive knowledge base and inferential processing in order to understand at a basic level.

Thus, the comprehensibility problems of interest concern the surface structure of the sentences, the surface structure of the text, especially with regard to issues such as cohesion and coherence, and aspects of the content of the text at the shallow semantics level (see Kieras, 1985b). By shallow semantics is meant the content of sentences at the level of the immediate propositional content, such as that described by Kintsch (1974). At this level, semantic content is very closely related to the

surface structure of the sentences, and in fact can be automatically extracted from input text if it is syntactically simple enough. In a domain such as technical documents intended for military personnel, such a constraint is quite reasonable (see Kieras, 1985a).

Thus, this survey covers the psycholinguistics literature under the following constraints: (1) The results must be obtained empirically, rather than as result of linguistic analysis. (2) The independent variable must be some manipulation of surface structure either of sentences or text, or a content manipulation or property at the shallow semantic level. (3) The dependent variable must be some measure related to comprehension.

SUMMARY OF SURVEY RESULTS

Approximately 170 papers, spanning the years from 1950 to 1985 were examined and summarized. This is certainly not an exhaustive survey, but is probably a representative one. Fifty-nine rules for comprehensible writing are proposed, and the literature will be reviewed below in terms of the specific rules. The Appendix contains an index to the studies that briefly summarizes the major dependent variables and type of materials used.

It must be kept in mind that most of the studies were not done with the goal of arriving at rules for comprehensible writing. Normally, the researchers had some theoretical question in mind, and in many cases these goals differ substantially from those of current research in the field of comprehension. For example, much of the research on the effect of sentence surface structure was done in the context of the classical psycholinguistic concern with transformational grammar. Since transformational grammar plays little role in current work on comprehension, these papers often seem anachronistic. However, they contain a wealth of empirical results on different forms of surface structure. The purpose of this report is to collect these results and organize them in terms of rules for comprehensible writing, independently of the original goals and motivations for the research.

Another important consideration to keep in mind is that the experiments surveyed used a variety of experimental tasks. Most of the work on how people process language has been done in the context of memory tasks, as if the major function of language was to provide material for the reader to memorize. But work such as Sticht (1977) shows that such reading for memorization is relatively rare in real world tasks. In contrast, very little of the empirical literature involves paradigms in which people have to carry out some "job" by reading the material.

A common assumption running throughout this literature is that comprehension can be measured in a variety of indirect ways. Perhaps the clearest example is the case of recall measures. It has been an implicit assumption that more comprehensible material will be remembered better, apparently because more comprehensible material will produce a better representation in memory, leading to better recall, and also because the reader will have more processing resources to expend on memorizing the material. To the extent that all of the measures are assumed to have corresponding properties the results of all of the studies provide information about comprehension. The problem is that the nature of the reading task involved with a particular measure can change the size, and even the direction of experimental effects. Thus, the reader should keep in mind that all of the effects discussed are possibly task-dependent.

Another important consideration is the type of materials used in the studies. Most of the psycholinguistics literature covered in this report deals with isolated sentences, rather than connected discourse. While this is clearly appropriate for some issues, it is also clear that there are many processes involved in comprehension that cannot be addressed in this way. A small proportion of the literature uses the minimal form of discourse, namely pairs of sentences. Finally, a small, but rapidly growing set of studies make use of multiple-sentence passages, or prose.

In most of the studies of prose, the materials have been stories, rather than technical materials. There should not be any substantial differences between technical and nontechnical prose at the level of the comprehensibility rules discussed in this report. The difference between these two types of prose would appear either at the vocabulary level, or at the deep semantic level, where organizational structures such as story schemas would come into play (see Kieras, 1985b). Since rules involved with the deep semantics are not included, the comprehensibility rules in this report should be equally applicable to technical and nontechnical prose.

COMPREHENSIBILITY RULES

Overview

The results of the survey are organized in terms of a series of rules. Following the statement of each rule, a brief discussion of its justification will appear, which will include citations of the experimental papers upon which this rule is based. The rules group into three major categories. The first is sentence level. These rules deal with aspects of comprehensibility that appear only at the level of single sentences. There are a large number of rules at this level, most

of which are based on the classic work in psycholinguistics on the effects of different syntactical forms. The topics in this literature are fairly few; it should be remembered that this literature was dominated by theoretical considerations in transformational grammar, and only a few problems were considered relevant. For example, there are a large number of studies comparing self-embedded with right-branching sentence structure, even though it is clear that self-embedded sentences are extremely rare in natural prose.

The second major section is concerned with integration of text content. Given that a text consists of a series of sentences, the task of the reader is to integrate the content of these sentences into a representation of the meaning of the entire passage. The groups of rules that are related to this integration process are concerned with the relationships between the propositional content of sentences, the topic-comment structure within each sentence, the directness of reference in the noun phrases within the sentence, the use of pronouns, and the global order of information within the text.

The final group of rules are concerned with the choice of text content at the shallow semantic level. Even though the bulk of the rules are concerned with how information is presented, as opposed to how the information is chosen, there are rules for comprehensible writing that concern the choice of content at a shallow, rather than deep, semantic level. For example, if the topic of a passage rarely appears as an argument of the propositions in the passage, something must be wrong. The groups of rules concerned with text content choice have to do with the structure of text content, the intended main ideas and items, the amount of information in the passage, and the relationship of textual markers to the intended content of the text.

Sentence Level

Lexical Choices

Use common high frequency words where appropriate. Low frequency words are harder to comprehend than low frequency words (e.g., Cairns & Foss, 1971; Frederiksen, 1979; Foss, 1969).

Avoid ambiguous words. Several studies have shown that ambiguous words produce the expected effect of impairing comprehension (Foss, 1970; Mistler-Lachman, 1972; Bever, Garrett & Hurtig, 1973). However, as discussed below, the effect of lexical ambiguity is not as serious as other forms of ambiguity.

Sentence Complexity

Avoid complex syntax. This is an obvious rule, with at least one empirical demonstration (Kintsch & Monk, 1972). The problem is to define reasonable measures of syntactic complexity that can be used in guidelines for when a sentence is too complex. A classical measure of complexity is the Yngve depth, which is based on the phrase structure of the sentence. Many studies have shown that sentences with low average depth are comprehended better than high depth sentences (Roberts, 1968; Wang, 1970; Wearing, 1970). However the effect of depth depends on the sentence type and structure (Roberts, 1968; Martin, Roberts & Collins, 1968; Perfetti, 1969a,b), and there are some reports that the Yngve depth is not always an effective predictor of performance (Johnson, 1965; Perfetti, 1969b). Thus, a more general interpretation of these results is that more complex sentences must put more processing load on the reader. This leads to the following rule:

Don't overload the reader's processing capacity. Since the human information processing system can only handle a limited amount of information, the limit to the complexity of sentence syntax should be based on the processing capacity. Some studies have shown that there are chunking effects in sentences, such as Levelt (1970), Miller (1962), and Johnson (1968). Apparently, phrases, clauses, and sentences are the units by which language is comprehended (Johnson, 1968; Caplan, 1972; Holmes & Forster, 1972a; Fodor & Bever, 1965; Garrett, Bever & Fodor, 1966; Bever & Hurtig, 1975; Jarvella, 1970, 1971; Jarvella & Herman, 1972). A common assumption in much of this work is that syntactic processing uses the traditional short-term memory to hold the phrase being processed and the intermediate results. Thus, it seems reasonable that the limitation on processing can be stated in terms of the roughly five chunks that can reside in short-term memory, although it is not clear that the short-term memory system is used in this way during ordinary comprehension. It does seem reasonably consistent with the literature to suppose that if the input becomes syntactically complex, large amounts of information will have to be stored in short-term memory.

However, limitations on syntactic processing should be handled by rules which forbid specific syntactic constructions. For example, it is known that too many self-embeddings can quickly lead to a breakdown in comprehension, apparently because short-term memory capacity is overloaded. Rather than expressing this result in terms of short-term memory load, it makes more sense to simply state a rule that this specific structure should not be used. The subject of short-term memory limitations on the content of sentences will be taken up below.

Prefer simple to complex sentences. Studies by Forster and Ryder (1971) show that simple sentences that contain one clause

are comprehended better than complex sentences that contain two clauses. Moreover, in complex sentences, the information in the subordinate clause is often lost (cf. Jarvella & Herman, 1972), and the greater syntactic complexity seems to obscure the sentence meaning as well (Forster & Ryder, 1971).

Overall Sentence Syntax

Use a consistent syntax; don't change for the sake of variety. Many textbooks on writing suggest that variety in style is good because it keeps up the interest of the reader. However, several studies show that variety in syntax is not a good idea. Wisher (1976) showed that a consistent syntactic form for sentences in passages yielded faster reading and better recall. Mehler and Carey (1967) showed that if a sentence had a different surface structure from the previous ones, it was not perceived as accurately. Tannenbaum and Williams (1968) showed a similar consistency effect for active and passive sentences.

Use common, expected syntactic structure. Graesser, Hoffman, and Clark (1980) defined a measure of predictability of syntax based on whether each word in the sentence had the syntactic class that was most likely to appear in the context of the previous words in the sentence. Sentences with more predictable syntax were read faster; however, the effects were fairly small.

Avoid ambiguous syntactic forms. Three types of syntactic ambiguity have been examined. In lexical ambiguity, single lexical items have multiple meanings, as in Be sure that you take the right turn. In surface structure ambiguity, the proper parse of the sentence is ambiguous. For example, consider carefully in The paper presented carefully limited analyses of the problem. In underlying structure ambiguity, the intended immediate representation of the sentence content is unclear, as in The shooting of the Indians bothered the agent. (Examples from Bever, Garrett & Hurtig, 1973). Studies such as Foss (1970), Mistler-Lachman (1972), and Bever, Garrett and Hurtig (1973), show that ambiguous forms are more difficult to comprehend than unambiguous sentences. More interestingly though, the results show that underlying structure ambiguity is worse than lexical or surface structure ambiguity, which are of similar difficulty (Bever, Garrett & Hurtig, 1973; Foss, 1970). However, the specific effects of ambiguity are both task-dependent (Mistler-Lachman, 1972; Foss, 1970) and depend on the sentence form (Mistler-Lachman, 1975).

Prefer active, then passive, then negative, finally negative-passive forms. There are a very large number of comparisons of the basic transformational forms (Slobin, 1966; Savin & Perchonock, 1965; Mehler, 1963; Miller & McKean, 1964; Gough, 1965, 1966; Morris, Rankine, & Reber, 1968; Howe, 1970;

Martin & Roberts, 1966). Active sentences are by far the most comprehensible, followed by passive, then negative sentences, with negative passives being the least comprehensible.

Negation

Avoid negation. A result related the the one cited above is that negated sentences are more difficult to understand than their logically equivalent affirmative forms. This has been shown by many studies, such as Just and Carpenter (1971), Just and Carpenter (1976), and Vasquez (1981).

Put negation in the subordinate clause rather than in the superordinate clause. Thus, instead of It is not true that Joe likes frogs, use It is true that Joe doesn't like frogs (Just & Carpenter, 1976; Vasquez, 1981).

Avoid more than one negation. Sherman (1976) reports that more than one negation produces serious loss of comprehension, with a severe breakdown at three negations within a sentence. The multiple negations can be of different types, not only explicit negations but also negative verbs and adjectives. For example, a very difficult sentence to comprehend is He was four feet five inches tall and so no one doubted that he would be uncomfortable with very tall girls. Sherman's results suggest that the different forms of negation can be ordered in terms of decreasing complexity as not, un-adj, negative verbs, and no one.

Relative Clauses

Use subject relative clauses rather than object relative. A subject relative clause has the modified noun as the subject of the relative clause, as in The designer that praised the manager.... An object relative clause has the modified noun being the object of the clause, as in The designer that the manager praised.... Subject relative clauses are easier to understand than object relative clauses (Ford, 1983; Hakes, Evans, & Brannon, 1976; Sheldon, 1977; Baird & Koslick, 1974).

Use relative pronouns, especially in object relative clauses. A relative pronoun, such as that, is an unambiguous signal to the presence of a relative clause. However, lacking a relative pronoun is much more damaging in object relative clauses (Hakes, Evans & Brannon, 1976) and in self-embedded clauses (Fodor & Garrett, 1967; Hakes & Foss, 1970; Hakes & Cairns, 1970). There is a apparently little or no effect of relative pronouns for subject relative clauses (Hakes, Evans & Brannon, 1976; Bock & Brewer, 1974).

Avoid self-embedded constructions; use right-branching instead. The comparison of self-embedded with right-branching

constructions is one of the most popular topics in the psycholinguistic literature. The standard result is that self-embedded sentences are much harder to comprehend than right-branching (Schwartz, Sparkman & Deese, 1970; Foss & Lynch, 1969; Hakes & Foss, 1970; Foss & Cairns, 1970; Blaubergs & Braine, 1974; McDaniel, 1981; Hamilton & Deese, 1971; Sheldon, 1977; Townsend, Ottaviano & Bever, 1979). Apparently, one self-embedding can be comprehended, but increased embedding rapidly becomes extremely difficult to comprehend. At three or four embeddings, there is essentially no comprehension (Marks, 1968; Schwartz, Sparkman & Deese, 1970; Blaubergs & Braine, 1974). A similarly powerful effect appears to be lacking for right-branching; apparently one need not worry about the depth of right-branching embedding (Marks, 1968; Hamilton & Deese, 1971; Schwartz, Sparkman & Deese, 1970; Blaubergs & Braine, 1974).

Verb Forms

Past tense is better than present perfect. Miller and McKean (1964) showed that sentences such as John liked the small boy were more comprehensible than sentences John had liked the small boy.

Keep verbal particles close to the verb. Bock and Brewer (1974) showed that two-part verbs such as figure out were understood better if the particle, such as out, was kept next to the verb instead of being moved to the end of the sentence.

Prefer active to passive under normal circumstances. The comparison of different transformations is one demonstration of this rule. There are many other experiments that directly compare comprehension of logically equivalent active and passive sentences, and confirm that active sentences are more comprehensible than passive. Rather than list these, it is far easier to describe the exceptions and qualifications to this rule. Gough (1966) showed that the active is still better, even if the passive voice is in a shorter form. Bacharach and Kellas (1971) showed that active was better than the passive, which was similar to sentences in which the by-phrase was replaced by a manner adverbial phrase. Herriot (1969) and Slobin (1966) showed that the superiority of the active voice mainly applies to cases where the relationship between the logical subject and object is not obvious on semantic grounds. For example, if the semantics of the relation between the two items is such that only one of them can be the logical subject, then there is no difference between the comprehensibility of active and passive voices.

Use the passive voice when the logical object is the current focus or topic. A blanket ban of the passive voice is unjustified. Linguistically, the function of the passive voice is to allow the logical object to be the surface subject of the sentence, which is desirable when the logical object is the

Ford, M. (1983). A method for obtaining measures of local parsing complexity throughout sentences. Journal of Verbal Learning and Verbal Behavior, 22, 203-218.

Forster, K. I., & Ryder, L. A. (1971). Perceiving the structure and meaning of sentences. Journal of Verbal Learning and Verbal Behavior, 10, 285-296.

Foss, D. J. (1969). Decision processes during sentence comprehension: Effects of lexical item difficulty and position upon decision times. Journal of Verbal Learning and Verbal Behavior, 8, 457-462.

Foss, D. J. (1970). Some effects of ambiguity upon sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 9, 699-706.

Foss, D J. & Cairns, H. S. (1970). Some effects of memory limitation upon sentence comprehension and recall. Journal of Verbal Learning and Verbal Behavior, 9, 541-547.

Foss, D. J. & Lynch, R. H., Jr. (1969). Decision processes during sentence comprehension: Effects of surface structure on decision times. Perception and Psychophysics, 5, 145-148.

Franks, J. J., & Bransford, J. D. (1974). Memory for syntactic form as a function of semantic context. Journal of Experimental Psychology, 103, 1037-1039.

Frase, L. T. (1973). Integration of written text. Journal of Educational Psychology, 65, 252-261.

Frederiksen, J. R. (1979). Component skills in readers of varying ability. Naval Research Reviews, 32, 24-41.

Garrett, M., Bever, T., & Fodor, J. (1966). The active use of grammar in speech perception. Perception and Psychophysics, 1, 30-32.

Garrod, S., & Sanford, A. (1977). Interpreting anaphoric relations: The integration of semantic information while reading. Journal of Verbal Learning and Verbal Behavior, 16, 77-90.

Glynn, S. M. (1978). Capturing readers' attention by means of typographical cuing strategies. Educational Technology, November, 7-12.

Glynn, S. W., & Di Vesta, F. J. (1977). Outline and hierarchical organization as aids for study and retrieval. Journal of Educational Psychology, 69, 89-95.

Caplan, D. (1972). Clause boundaries and recognition latencies for words in sentences. Perception and Psychophysics, 12, 73-76.

Carpenter, P. A., & Just, M. A. (1977). Integrative processes in comprehension. In D. LaBerge & S. J. Samuels (Eds.), Perception and Comprehension(pp. 217-241). Hillsdale, N. J.: Lawrence Erlbaum Associates.

Charrow, V. R., & Redish, J. C. (1980). A study of standardized headings for warranties (Document Design Project Technical Report No. 6). American Institutes for Research.

Clark, H. H. (1973). Comprehension and the given-new contract. Paper prepared for conference on The Role of Grammar in Interdisciplinary Linguistic Research. University of Bielefeld, Bielefeld, Germany.

Clark, H. H., & Haviland, S. E. (1977). Comprehension and the given-new contract. In R. O. Freedle (Ed.), Discourse processes: Advances in research and theory, 1. Norwood, New Jersey: Ablex Publishing Corporation.

Clark, H. H., & Sengul, C. J. (1979). In search of referents for nouns and pronouns. Memory and Cognition, 7, 35-41.

Di Vesta, F. J., Schultz, C. B., & Dangel, T. R. (1973). Passage organization and imposed learning strategies in comprehension and recall of connected discourse. Memory and Cognition, 1, 471-476.

Dixon, P. (1982). Plans and written directions for complex tasks. Journal of Verbal Learning and Verbal Behavior, 21, 70-84.

Ehrlich, K., & Johnson-Laird, P. N. (1982). Spatial descriptions and referential continuity. Journal of Verbal Learning and Verbal Behavior, 21, 296-306.

Fodor, J. A. & Bever, T. G. (1965). The psychological reality of linguistic segments. Journal of Verbal Learning and Verbal Behavior, 4, 414-420.

Fodor, J. A., & Garrett, M. F. (1967). Some syntactic determinants of sentential complexity. Perception and Psychophysics, 2, 289-296.

Fodor, J., Garrett, M. & Bever, T. G. (1968). Some syntactic determinants of sentential complexity, II: Verb structure. Perception & Psychophysics, 3, 453-461.

comprehension mechanisms involved, or even the linguistic properties of such topic structures. Clearly research is needed to determine the desirable properties of such topic structures.

REFERENCES

Bacharach, V. R., & Kellas, G. (1971). Phrase versus base structure effects on short-term retention. Journal of Verbal Learning and Verbal Behavior, 10, 171-175.

Baird, R., & Koslick, J. D. (1974). Recall of grammatical relations within clause-containing sentences. Journal of Psycholinguistic Research, 3, 165-171.

Bever, T. G., Garrett, M. F. & Hurtig, R. (1973). The interaction of perceptual processes and ambiguous sentences. Memory and Cognition, 1, 277-286.

Bever, T. G., & Hurtig, R. R. (1975). Detection of a nonlinguistic stimulus is poorest at the end of a clause. Journal of Psycholinguistic Research, 4, 1-7.

Blaubergs, M. S., & Braine, M. D. S. (1974). Short-term memory limitations on decoding self-embedded sentences. Journal of Experimental Psychology, 102, 745-748.

Blumenthal, A. L. & Boakes, R. (1967). Prompted recall of sentences. Journal of Verbal Learning and Verbal Behavior, 6, 674-676.

Bock, K. J., & Brewer, W. F. (1974). Reconstructive recall in sentences with alternative surface structures. Journal of Experimental Psychology, 103, 837-843.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. Journal of Verbal Learning and Verbal Behavior, 11, 717-726.

Britton, B. K., Meyer, B. J., Hodge, M. H., & Glynn, S. M. (1980). Effects of the organization of text on memory: Tests of retrieval and response criterion hypothesis. Journal of Experimental Psychology: Human Learning and Memory, 6, 620-629.

Cairns, H. S., & Foss, D. J. (1971). Falsification of the hypothesis that word frequency is a unified variable in sentence processing. Journal of Verbal Learning and Verbal Behavior, 10, 41-43.

parallel-tuned network Z106 have the function of introducing a referent which is later going to be referred to by the symbol Z106, and also provides a description of this referent, namely that it is a parallel-tuned network. Since language of this sort has not been studied in any detail, it is presently unknown whether these forms of reference are fundamentally different from those that have already been studied. One crucial issue that has seen very little research is the processes by which such references are integrated with the content of graphical illustrations such as circuit diagrams.

Complex Forms of Reference

A common form of reference in technical material is the use of associated noun phrases (Huckin & Olsen, 1983). In this form of reference, there is little overlap between the linguistic structure of the noun phrases that introduce the referent and those that refer to it. Consider this simple example: The temperature of the cathode determines the rate of electron emission. As the cathode temperature rises, more electrons are emitted. First, notice that the reference the cathode temperature does not directly correspond to the noun phrase the temperature of the cathode, although this same words are used. The phrase electrons are emitted is strongly related to the rate of electron emission, but the structures are radically different. A more complex example appears in Huckin and Olsen (1983): The thermal properties of glassy materials.... The thermal conductivity.... The specific heat below 4K.... Some progress has been made toward understanding the thermal behavior.... All of these references have something to do with heat and thermal properties, and as a result, the entire passage is coherent, but there are no explicit shared referents. The problem for future research is to determine whether such complex forms of reference should be avoided in order to make prose comprehensible, and how complex the reference can be before it is unacceptable.

Procedural Text Form and Content

Although vast quantities of procedural text are written and read constantly, at this time there has been very little work on the desirable properties of such text and theoretical analyses of the comprehension processes involved. The work cited above under the heading of instruction sentences is clearly just a beginning on this extremely important topic.

Topic Structures

Extended discourse goes from one topic to another. Each paragraph may begin with a topic which is different from the previous paragraph topic, and within a paragraph the local topic can change constantly. Very little is known about the

Topics for Future Research

Sentence Complexity

The complexity of sentences is clearly an important issue, as shown by the following example from a draft of military training materials: Upon completion of this lesson you will able to perform independently or as a member of a team the preventive maintenance checks on the mock-up of a twin agent fire extinguishing system following procedures specified on the MRCs provided and to the satisfaction of the instructor. This sentence is obviously too long. However, the common approach of setting a simple cut-off on sentence length is clearly unsatisfactory because it is an entirely unprincipled approach. Some very long sentences are in fact considerably easier to understand than this example.

But, despite the roughly twenty years of research, a theoretically justified characterization of sentence complexity is still lacking. First of all, a clearer description of when syntactic form is actually important is needed. There are many suggestions in the literature (e.g., Kieras, 1981b) that the syntactic parsing process in reading takes very little time compared to the processes of storing and integrating sentence meanings. This suggests that the complexity of sentence syntax is actually not very important unless extreme complexity is present. However, this question has not been systematically investigated.

One possible criterion for when a sentence is too complex can be based on models such as Kintsch and van Dijk (1978): since sentence processing uses short-term memory, a sentence should be limited to about five propositions of new information. The above example exceeds this guideline by a factor of at least two or three. An important topic for further research is not only whether it is possible to define sentence complexity limitations in terms of such a straightforward measure of amount of propositional content, but also whether the purely syntactic complexity of the sentence contributes as well. Notice that in large complex sentences, the syntactic complexity is likely to be strongly confounded with the amount of sentence content.

Terminology and Reference

There is almost no work on the type of terminology appearing in technical prose. An example from an actual equipment manual illustrates this type of terminology: The amplified 225.00 to 399.95 MHz rf output of V104 is coupled by C126 to parallel-tuned network Z106 which offers a high impedance to the rf signal. The terminology used here is a mixture of conventional abbreviations, such as V104, which are often references to objects in a diagram. Phrases such as

the propositions in a text is a predictor of comprehension difficulty (Manelis & Yekovich, 1976; Kintsch, Kozminsky, Streby, McKoon & Keenan, 1975; Graesser, Hoffman & Clark, 1980). There are ways to define arguments that makes this result equivalent to the following one, that the number of propositions should be kept low (see Kieras, 1981b; Kintsch, et. al, 1975).

Keep the number of propositions low. A basic result was reported in Kintsch (1974), that comprehension time is mainly a function of the number of propositions rather than the number of words. Further confirmation was supplied by Yekovich and Manelis (1980), Graesser, Hoffman and Clark (1980), and Kieras (1981b). Thus eliminating unnecessary propositions should improve performance.

Textual Markers

Ensure that markers agree with intended content. There are a large variety of ways to mark information as being important, or in need of the readers attention, such as underlining, titles, and headings. Glynn and Di Vesta (1979) and Glynn (1978) showed that typographical cues increased recall. Clark (1973) argued that titles should improve comprehensibility, as was demonstrated in the Bransford and Johnson (1972) studies of the effect of context provided by titles. Studies by Kozminsky (1977), Charrow and Redish (1980), and Swarts, Flower and Hayes (1980) suggest that titles and headings should match the intended content because the reader attempts to make use of them. Kieras (1985b) discusses the effects of thematic markers such as the important point is that.... Based on the current literature, such markers have only weak effects, but clearly they should only mark material that is in fact intended to be important.

CONCLUSION

Summary

The work reviewed above can be briefly summarized. There was an early focus on syntax in the psycholinguistics literature, but because this work tended to focus on limited theoretical issues, it was not very comprehensive. The work on text integration has focused mainly on the role of individual referential forms in brief passages. It provides some important rules for establishing coherence. The role of larger structures in integration has been very little studied. The work on shallow semantic content provides a fundamental characterization of how readers process the content of prose and leads to some specific rules for the choice of amount and content. However, the most recent focus of comprehension research has been heavily on deep semantics, which was not reviewed here since it is not as immediately relevant to improving the quality of writing.

Choice of Text Content

As described in the introduction to this report, the choice of content at the deep semantic level is not considered here. But there are important choices of text content that can be defined in terms of the shallow semantic properties of the material. These properties can be described in terms of sentence propositions and their arguments.

Text Content Structure

Ensure that important information is high in the content structure. A hierarchy of the propositions in a text can be defined by starting at a particular proposition and subordinating all the propositions that share arguments with the starting proposition. This process can be applied at each level of the hierarchy until all text propositions have been subordinated in the structure. An important result is that information that is near the top of the hierarchy is remembered better than information at lower levels (Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975; Britton, Meyer, Hodge, & Glynn, 1980; McKoon, 1977; Meyer, 1977). This "levels effect" implies that important information should be high in the content structure of the passage. In other words, the proposition that expresses the main point should have arguments that many other propositions refer to (Kieras, 1978; Manelis, 1980).

Main Ideas and Items

A paragraph should be about one main item rather than several. The main item of a passage should be the most frequently mentioned sentence subject. The main idea of a paragraph should be about the main items. These rules follow from Kieras (1979, 1981a), who did a series of studies investigating the main idea of paragraphs, which corresponds intuitively to the "point" of the paragraph, and the main items of paragraphs, which correspond to the referent that the paragraph is "about".

Avoid unnecessary details. A typical text will have some main ideas, and in addition, include details about the main ideas or main items. Reder and Anderson (1982) have demonstrated convincingly that if the goal is to have the reader understand and remember the main ideas, the details actually interfere with performance. Note that given the main ideas, the details can often be defined at the shallow semantic level.

Amount of Information

Keep the number of propositional arguments low. Studies have shown that the number of different arguments appearing in

Use of Pronouns

Subject pronouns should refer to the previous sentence subject rather than the object. Avoid sentences that intervene between the pronoun and the antecedent. A pronoun should have only one possible referent. These rules follow from a series of studies performed by Frederiksen (1979) on how good and poor readers understand pronouns.

Repeated noun phrases can be easier than pronouns. Frederiksen (1979) obtained this result for poor readers, which suggests that even good readers would find repeated noun phrases somewhat easier than pronouns. Of course, reading time is a function of the number and length of words that must be viewed, so this rule is not unambiguous.

Use a pronoun in the second pair of sentences with the same subject conjoined with "and". This result was obtained by Lesgold (1972) and Bock and Brewer (1974). It appears to contradict the above rule from Frederiksen (1979).

Order of Information Within A Text

A text can be viewed as a syntactic structure in the same manner as a sentence. Text syntax concerns the order of sentences or sentence information, rather than the order of words. However, unlike sentence syntax, the investigation of desirable text syntax has been quite limited.

Group by name rather than by attribute. If a paragraph contains descriptions of attributes of several objects, it is better to arrange the information so that sentences about the same object, rather than the same attribute, are contiguous. For example, rather than describing the colors of all objects first, followed by their shapes, and so forth, it is better to describe all of the attributes of an object, and then go on to the next object (Di Vesta, Schultz & Dangel, 1973; Frase, 1973). Note that this distinction appears at the shallow, rather than deep, semantic level.

Use a hierarchical paragraph structure when appropriate. If the material in a paragraph conforms to a hierarchical structure, it is best to present the material in such a way that preserves the contiguity of elements within the hierarchy (Glynn & Di Vesta, 1977). Note that under reasonable constraints, the appropriate order of information can be defined at the shallow semantic level.

Put the main idea at the beginning of a paragraph. This traditional concept of the "topic sentence" was demonstrated experimentally by Kieras (1980). A discussion of the theoretical mechanisms involved is presented in Kieras (1985a).

of bridging inferences required by a text was a strong predictor of the comprehensibility and memorability of the material.

Introduce a referent explicitly, rather than let it be implied. One of the ways to make reference resolution simple is to introduce a new item in a direct manner, so that the reader definitely knows that the object has been introduced and will probably be referred to later. For example, Singer (1979), Clark (1973), and Haviland and Clark (1974) compared sentence pairs such as The boy used a shovel. The shovel was heavy with pairs such as The boy hated working with a shovel. The shovel was heavy. In the first case the first sentence requires the reader to postulate a particular shovel that the boy was using, making the antecedent of the shovel in the second sentence explicit. In the second pair, the first sentence does not require the reader to postulate a particular shovel, but merely stated a relationship between the boy and shovels in general, meaning that the antecedent of the shovel is only implied by the first sentence, as opposed to being explicitly introduced. Comprehension of the second sentence, which refers to the shovel, was faster in the first case, when the particular referent has been explicitly introduced.

Make the reference direct, rather than inferential. The above rule concerns how an antecedent is originally introduced. A related effect concerns how an antecedent is referred to later. Walker, Jones, and Mar (1983) found that referring to the superset for an antecedent, which requires some inference to understand, was slower than referring directly to the antecedent. A related effect was obtained by Garrod and Sanford (1977), who found that while an antecedent originally appearing as an exemplar of a category could then be referred to by the category name, the opposite arrangement impaired comprehension. Thus, if a truck is under discussion, it can be referred to as the vehicle. Such a category reference will be slower than referring directly to the truck. However, if vehicles are the topic under discussion, referring to it with the truck is very bad.

Use consistent terminology; even synonyms are worse than repeated nouns. A common complaint about technical manuals for equipment is that the terminology is often inconsistent. This survey did not reveal any results directly bearing on this question, but Yekovich and Walker (1978) found that references in the form of synonyms were detectably slower than references in the form of repeated nouns. If even synonyms impair comprehension, further departures from consistency in reference should produce even more severe effects.

information. Simple declarative sentences, such as John is following Barb, have the surface subject marked as the given information, with the sentence predicate marked as the new information. Of course, the sentence predicate may contain references to objects already known, so the predicate will normally be a mixture of given and new information. In spoken English, emphasis or stress can be used to convey the given and new information structure of the sentence. Work by Singer (1976) and Carpenter and Just (1977) shows that violating these markings can substantially impair comprehension. Simple declarative sentences have relatively weak marking, but Harris (1975) found that following instructions to draw objects was easier if the object under discussion appeared as the subject of the sentences.

Directness of Reference in Noun Phrases

Noun phrases do most of the "work" in text integration, because they provide the references to previously mentioned objects. Thus, a critical process in text integration is identifying the prior referent for each noun phrase. The ease of this process is strongly related to the ease of comprehension.

Use definite reference only when the referent has already been introduced. A definite reference is a noun phrase introduced with the definite determiner the. Clark (1973) argues that this form of reference is a very strong signal that the referent has already been introduced. Using sentences in which the nouns were not repeated, de Villiers (1974) found that definite articles led readers to perceive a sentence list as a connected story, but using indefinite articles (a, an) caused readers to perceive the sentences as unrelated. Thus, definite articles very strongly direct the reader to find connections between sentences in the form of shared referents.

Restrictive relative clauses should contain only given information. The normal role of a restricted relative clause is to specify a referent, as in The car that Joe races.... Given this role, such a relative clause should contain only given information and should not be used to introduce new information, as in The car which Joe races... (Clark, 1973). This, of course, is consistent with the standard use of which and that.

Keep reference resolution simple; don't make the reader infer connections. Work by Clark (1973), Haviland and Clark (1974), Clark and Haviland (1977), Miller and Kintsch (1980), and Kintsch and Vipond (1979) shows that the cost of making inferences in order to resolve references is quite high. Such bridging inferences can require fairly complex reasoning based on general knowledge. In the work on readability by Miller and Kintsch (1980) and Kintsch and Vipond (1979), the number

A new item that is focused on should be presupposed in the next sentence. A common construction in text is that a new referent is introduced and then later sentences provide more information about this referent. Yekovich, Walker, and Blackman (1979) showed that if a new item occupies a focus position in the sentence when it is introduced, such as the fire in The vandals started the fire in the basement with kerosene, then the reader has the expectation that further information about the item will be forthcoming, which means that the item should be marked as given or presupposed information in the next sentence.

Prefer other forms to conjunction of sentences with "and". Instead of stringing together information in short sentences with and, use unrestricted relative clauses or prenominal adjectives in sentence predicates. For example, Lesgold (1972) showed that sentences like The blacksmith was skilled and the anvil was dented and the blacksmith pounded the anvil were comprehended worse than sentences like The blacksmith was skilled and he pounded the anvil which was dented or The skilled blacksmith pounded the dented anvil.

Use connectives when appropriate. Connectives are words like however and therefore. Such words make explicit the relations between sentences such as causal connections or adversative relationships (Carpenter & Just, 1977). Haberlandt and Kennard (1981) showed that if a sentence had such a relation to the prior sentence, it was comprehended faster if the connective word was present. There is some indication that the adversative relationship was understood faster than a causal relationship. Hoosain (1974) found that words such as before and after were understood better than words such as while, because, and in order to.

Topic-Comment Structure of Sentences

A concept name should be the topic, the description should be the comment. Rothkopf (1963) examined sentences that defined concepts, with either the name or the description of the concept being in the topic (surface subject) position in the sentence. Performance was better when the name occupied the topic position.

Adverbs like "either" and "again" assume presupposed information. This follows from results reported in Clark (1973).

Put new information at the proper place in the sentence form. Considerable work has been done on given-new markings in individual sentences such as cleft and pseudo-cleft forms. These are sentences like It is John who is following Barb, in which John is strongly marked as the new information and who is following Barb is strongly marked as the given or presupposed

Integration of Text Content

Inter-sentence Relations

Propositional representation. Most of the work on text integration and text content uses the theoretical concept of propositional representations for the text content. A proposition is an elementary unit of information that consists of a logical relation that takes one or more arguments. Normally, the arguments represent referents, which are the objects under discussion. In the course of comprehending a text, the reader will extract the propositions from the individual sentences and attempt to store them in memory. Since the propositions are related to each other by being about the same referents, the relationships of the propositional arguments to each other is an important aspect of what makes text comprehensible. Clark (1973; Clark & Haviland, 1977) has described the given-new mechanism; each sentence in a discourse provides some new information about referents that are already known, or given in the context of the preceding sentences. The reader's task is thus to identify the given items in each sentence, locate the corresponding memory representations, and attach the new information to them (Kieras, 1981b).

Produce coherence by repeating arguments. The basic way in which sentence meanings are integrated is that the sentence propositions share the same arguments. Thus, Manelis and Yekovich (1976) and Yekovich and Manelis (1980) found that brief passages in which arguments were repeated between sentences were recalled better than those that were not.

Avoid temporary incoherence; connect sentences immediately. A basic process in sentence integration is resolving the references in a sentence with the prior referents. If this can not be done immediately, then presumably the sentence information has to be kept in some form of short-term memory and integrated later, resulting in a higher processing load. Such effects were observed by Kieras (1978) and Ehrlich and Johnson-Laird (1982). Based on the Kintsch and van Dijk (1978) processing model, roughly two propositions are held in short-term memory from one sentence to the next. If a reference cannot be resolved within these two propositions, long-term memory search is necessary, resulting in a substantial increase in reading time and poorer recall (Miller & Kintsch, 1980; Kintsch & Vipond, 1979). Thus, references should be to objects mentioned very recently. Carpenter and Just (1977) found that sentences intervening between a reference and its antecedent made processing difficult. Clark and Sengul (1979) found that pronoun antecedents should appear in the clause one back from the current sentence.

main-subordinate order. Townsend, Ottaviano and Bever (1979) found that probe memory of the verb was better with the main clause first, and Holmes (1973) found that adverbial clauses should be last. However, Jarvella and Herman (1972) found that recall was better for the opposite order.

Put adverbs that modify the main verb at the end of the sentence. This effect was obtained by Roberts (1968) and Bock and Brewer (1974).

Prefer direct object followed by indirect object ordering. Waryas and Stremel (1974), in a fairly comprehensive study, found that the form direct object to indirect object was preferable to the opposite order, unless the indirect object was a pronoun and the direct object was a noun. Thus, John gave the apple to the captain is preferable to John gave the captain an apple. However, John gave him the apple is preferable to John gave the apple to him. Thus, if the indirect object is a pronoun and the direct object is a noun, the indirect object should appear first. However, Bock and Brewer (1974) obtained contrary results, but they considered only the case in which both the direct and indirect objects were nouns.

Instruction sentences

Put items in the order of execution. Research on the comprehension of instructions is just beginning, but the available results show that items in the instruction sentences should appear in the same order as the corresponding items have to be operated on. Greenfield and Westerman (1978) demonstrated this in a task where subjects arranged a set of cups according to simple or complex sentence instructions. In many cases, sentences that state instructions contain a prior condition that must be true, the action to be done, and the goal to be achieved. These constituents should appear in the sentence in the same order as they are needed when the instruction is carried out. Thus condition, action and goal are probably the desired order (Spoehr, Morris & Smith, 1984; Dixon, 1982).

Instructions should translate easily to production rules. Kieras (1985c) found effects consistent with the hypothesis that since the internal representation of a procedure is in the form of production rules (independent IF-THEN constructions), instructions on how to carry out a procedure should be presented in a form that permits this translation to occur most easily. This is clearly related to the above rule, but further research on this topic is definitely needed.

focus or topic of the discourse. The desirability of the passive voice in this situation has been shown by Tannenbaum and Williams (1968), Perfetti and Goldman (1974, 1975), and Turner and Rommetveit (1968). Under some circumstances, there appears to be no harm in using the truncated passive, which is a passive sentence with the actor by- phrase missing (Slobin, 1968; Franks & Bransford, 1974). However, Martin and Roberts (1966) found that truncated passive sentences were recalled worse than full passives.

Complements

Examples of sentence complements. A subject complement specifies the sentence subject, and uses either an -ing verb or that: The girl's leaving home so suddenly amazed all her friends; Your suggestion that Alan should conceal the truth alarmed him. An object complement appears as the sentence object, and can also be expressed with either -ing, or that: The lawyer resented my aunt giving orders to the staff; The vicar made the claim that the church was corrupt.

Use "that" to introduce sentence complements. Hakes (1972) compared sentences such as The blind student felt (that) the recent material in the art course was too difficult for him to understand with the complementizer that present or absent. In an effect similar to the use of that in relative clauses, the sentences were easier when that was present. Holmes (1973) showed that object complement constructions with that are easier than complement constructions based on the ing form of a verb.

Prefer object complements to subject complement constructions. Holmes (1973) showed that subject complements were more difficult to understand than object complements.

Use simple verbs rather than verbs that can take complements. Fodor and Garrett (1968) showed that sentences based on a simple transitive verb, such as The man whom the child met carried a box was easier to understand than sentences based on a verb that can take complements, such as The man whom the child knew carried a box. A similar result was obtained by Holmes and Forster (1972b), but Hakes (1971) found no difference.

Possessive Forms

Express possession with 's rather than "of". This rule follows from Bock and Brewer (1974).

Order of Sentence Constituents

Put main clause first, followed by subordinate clause. The experimental results on this question are not consistent, but the weight of the evidence seems to be in favor of the

Glynn, S. M., & Di Vesta, F. J. (1979). Control of prose processing via instructional and typographical cues. Journal of Educational Psychology, 71, 595-603.

Gough, P. B. (1965). Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior, 4, 107-111.

Gough, P. B. (1966). The verification of sentences: The effects of delay of evidence and sentence length. Journal of Verbal Learning and Verbal Behavior, 5, 492-496.

Graesser, A. C., Hoffman, N. L., & Clark, L. F. (1980). Structural components of reading time. Journal of Verbal Learning and Verbal Behavior, 19, 135-151.

Greenfield, P. M., & Westerman, M. A. (1978). Some psychological relations between action and language structure. Journal of Psycholinguistic Research, 6, 453-475.

Haberlandt, K., & Kennard, M. (1981). Causal and adversative connectives facilitate text comprehension. Paper presented at the Annual Meeting of the Psychonomic Society, Philadelphia, PA. November.

Hakes, D. T. (1971). Does verb structure effect sentence comprehension? Perception and Psychophysics, 10, 229-232.

Hakes, D. T. (1972). Effects of reducing complement constructions on sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 11, 278-286.

Hakes, D. & Cairns, H. (1970). Sentence comprehension and relative pronouns. Perception and Psychophysics, 8, 5-8.

Hakes, D., Evans, J. S., & Brannon, L. (1976). Understanding sentences with relative clauses. Memory and Cognition, 4, 283-290.

Hakes, D. T. & Foss, D. J. (1970). Decision processes during sentence comprehension: Effects of surface structure reconsidered. Perception and Psychophysics, 8, 413-416.

Hamilton, H. W., & Deese, J. (1971). Comprehensibility and subject-verb relations in complex sentences. Journal of Verbal Learning and Verbal Behavior, 10, 163-170.

Harris, L. J. (1975). Spatial direction and grammatical form of instructions affects the solution of spatial problems. Memory and Cognition, 3, 329-334.

Haviland, S. E., & Clark, H. H. (1974). What's new? Acquiring new information as a process in comprehension. Journal of Verbal Learning and Verbal Behavior, 13, 512-521.

Herriot, P. (1969). The comprehension of active and passive sentences as a function of pragmatic expectations. Journal of Verbal Learning and Verbal Behavior, 8, 166-169.

Holmes, V. M. (1973). Order of main and subordinate clauses in sentence perception. Journal of Verbal Learning and Verbal Behavior, 12, 285-293.

Holmes, V. & Forster, K. I. (1972a). Click location and syntactic structure. Perception and Psychophysics, 12, 9-15.

Holmes, V. M., & Forster, K. I. (1972b). Perceptual complexity and underlying sentence structure. Journal of Verbal Learning and Verbal Behavior, 11, 148-156.

Hoosain, R. (1974). The processing and remembering of congruent and incongruent sentences. Journal of Psycholinguistic Research, 3, 319-331.

Howe, Edmund S. (1970). Transformation, associative uncertainty, and free recall of sentences. Journal of Verbal Learning and Verbal Behavior, 9, 425-431.

Huckin, T., & Olsen, L. (1983). English for science and technology: A handbook for nonnative speakers. New York: McGraw-Hill.

James. C. T. (1972). Theme and imagery in the recall of active and passive sentences. Journal of Verbal Learning and Verbal Behavior, 11, 205-211.

James, C. T. (1972). Theme and imagery in the recall of active and passive voice. Journal of Verbal Learning and Verbal Behavior, 11, 205-211.

James, C. T., & Abrahamson, A. A. (1977). Recognition memory for active and passive sentences. Journal of Psycholinguistic Research, 6, 37-47.

Jarvella, R. J. (1970). Effects of syntax on running memory span for connected discourse. Psychonomic Science, 19, 235-236.

Jarvella, R. J. (1971). Syntactic processing of connected speech. Journal of Verbal Learning and Verbal Behavior, 10, 409-416.

Jarvella, R. J. & Herman, S. J. (1972). Clause structure of sentences and speech processing. Perception and Psychophysics, 11, 381-384.

Johnson, N. F. (1965). The psychological reality of phrase-structure rules. Journal of Verbal Learning and Verbal Behavior, 4, 469-475.

Johnson, N. F. (1968). The influence of grammatical units on learning. Journal of Verbal Learning and Verbal Behavior, 7, 236-240.

Just, M. A., & Carpenter, P. A. (1971). Comprehension of negation with quantification. Journal of Verbal Learning and Verbal Behavior, 10, 244-253.

Just, M. A., & Carpenter, P. A. (1976). The relation between comprehending and remembering some complex sentences. Memory and Cognition, 4, 318-322.

Kieras, D. E. (1978). Good and bad structure in simple paragraphs: Effects on apparent theme, reading time, and recall. Journal of Verbal Learning and Verbal Behavior, 17, 13-28.

Kieras, D. E. (1979). The relation of topics and themes in naturally occurring technical paragraphs (Technical Report No. 1). University of Arizona, Department of Psychology.

Kieras, D. E. (1980). Initial mention as a signal to thematic content in technical passages. Memory & Cognition, 8, 345-353.

Kieras, D. E. (1981a). The role of major referents and sentence topics in the construction of passage macrostructure. Discourse Processes, 4, 1-15.

Kieras, D. E. (1981b). Component processes in the comprehension of simple prose. Journal of Verbal Learning and Verbal Behavior, 20, 1-23.

Kieras, D. E. (1985a). The Potential for Advanced Computerized Aids for Comprehensible Writing of Technical Documents (Technical Report No. 17, TR-85/ONR-17). University of Michigan.

Kieras, D. E. (1985b). Thematic processes in the comprehension of technical prose. In B. Britton & J. Black (Eds.), Understanding expository text. Hillsdale, N. J.: Erlbaum.

Kieras, D. E. (1985c). Improving the Comprehensibility of a

Simulated Technical Manual. (Technical Report No. 20, TR-85/ONR-20). University of Michigan.

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

Kintsch, W., Kozminsky, E., Streby, W. J., McKoon, G., & Keenan, J. M. (1975). Comprehension and recall of text as a function of content variables. Journal of Verbal Learning and Verbal Behavior, 14, 196-214.

Kintsch, W., & Monk, D. (1972). Storage of complex information in memory: Some implications of the speed with which inferences can be made. Journal of Experimental Psychology, 94, 25-32.

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

Kintsch, W., & Vipond, D. (1979). Reading comprehension and readability in educational and psychological theory. In L. G. Nilsson (Ed.), Perspectives on Memory Research. Hillsdale, N. J.: Erlbaum.

Kozminsky, E. (1977). Altering comprehension: The effect of biasing titles on text comprehension. Memory & Cognition, 5, 482-490.

Lesgold, Alan M. (1972). Pronominalization: A device for unifying sentences in memory. Journal of Verbal Learning and Verbal Behavior, 11, 316-323.

Levelt, W. J. (1970). Hierarchial chunking in sentence processing. Perception and Psychophysics. 8, 99-103.

Manelis, L. (1980). Determinants of processing for a propositional structure. Memory & Cognition, 8, 49-57.

Manelis, L., & Yekovich, F. R. (1976). Repetitions of propositional arguments in sentences. Journal of Verbal Learning and Verbal Behavior, 15, 301-312.

Marks, Lawrence E. (1968). Scaling of grammaticalness of self-embedded English sentences. Journal of Verbal Learning and Verbal Behavior, 1, 965-967.

Martin, E. M., & Roberts, K. H. (1966). Grammatical factors in sentence retention. Journal of Verbal Learning and Verbal Behavior, 5, 211-218.

Martin, E. M., Roberts, K. H., & Collins, A. M. (1968). Short-term memory for sentences. Journal of Verbal Learning and Verbal Behavior, 7, 560-566.

McDaniel, M. A. (1981). Syntactic complexity and elaborative processing. Memory and Cognition, 9, 487-495.

McKoon, G. (1977). Organization of information in text memory. Journal of Verbal Learning and Verbal Behavior, 16, 247-260.

Mehler, J. (1963). Some effects of grammatical transformations on the recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 2, 346-351.

Mehler, J. & Carey, P. (1967). Role of surface base structure in the perception of sentences. Journal of Verbal Learning and Verbal Behavior, 7, 335-338.

Meyer, B. J. F. (1977). What is remembered from prose: A function of passage structure. In R. O. Freedle (Ed.), Discourse production and comprehension: Advances in research and theory, 1. Norwood, N. J.: Ablex Publishing Corporation.

Miller, G. A. (1962). Some psychological studies of grammar. American Psychologist, 17, 748-762.

Miller, G. A. & McKean, K. A. (1964). A chronometric study of some relations between sentences. Quarterly Journal of Experimental Psychology, 16, 297-308.

Miller, J. R., & Kintsch, W. (1980). Readability and recall of short prose passages: A theoretical analysis. Journal of Experimental Psychology: Human Learning and Memory, 6, 335-354.

Mistler-Lachman, J. L. (1972). Levels of comprehension in processing of normal and ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 11, 614-623.

Mistler-Lachman, J. L. (1975). Queer sentences, ambiguity, and levels of processing. Memory and Cognition, 3, 395-400.

Morris, Val Anne, Rankine, Fred C., & Reber, Arthur S. (1968). Sentence comprehension, grammatical transformations and response availability. Journal of Verbal Learning and Verbal Behavior, 1, 1113-1115.

Perfetti, C. A. (1969a). Lexical density and phrase structure depth as variables in sentence retention. Journal of Verbal Learning and Verbal Behavior, 8, 719-724.

Perfetti, C. A. (1969b). Sentence retention and the depth hypothesis. Journal of Verbal Learning and Verbal Behavior, 8, 101-104.

Perfetti, C. A., & Goldman, S. R. (1974). Thematization and sentence retrieval. Journal of Verbal Learning and Verbal Behavior, 13, 70-79.

Perfetti, C. A., & Goldman, S. R. (1975). Discourse functions of thematization and topicalization. Journal of Psycholinguistic Research, 4, 257-271.

Reder, L. M., & Anderson, J. R. (1982). Effects of spacing and embellishment on memory for the main points of a text. Memory and Cognition, 10, 97-102.

Roberts, Kelyn, H. (1968). Grammatical associative constraints in sentence retention. Journal of Verbal Learning and Verbal Behavior, 7, 1072-1076.

Rothkopf, E. Z. (1963). Learning from written sentences: Within-sentence order in the acquisition of name-clause equivalences. Journal of Verbal Learning and Verbal Behavior, 2, 470-475.

Savin, H. & Perchonock, E. (1965). Grammatical structure and the immediate recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 4, 348-353.

Schwartz, D., Sparkman, J. P., & Deese, J. (1970). The process of understanding and judgements of comprehensibility. Journal of Verbal Learning and Verbal Behavior, 9, 87-93.

Sheldon, A. (1977). On strategies for processing relative clauses: A comparison of children and adults. Journal of Psycholinguistic Research, 6, 305-318.

Sherman, M. A. (1976). Adjectival negation and the comprehension of multiply negated sentences. Journal of Verbal Learning and Verbal Behavior, 15, 143-156.

Singer, M. (1976). Thematic structure and the integration of linguistic information. Journal of Verbal Learning and Verbal Behavior, 15, 549-558.

Singer, M. (1979). Processes of inference during sentence encoding. Memory and Cognition, 7, 192-200.

Slobin, D. I. (1966). Grammatical transformations and sentence comprehension in childhood and adulthood. Journal of Verbal Learning and Verbal Behavior, 5, 219-227.

Slobin, D. I. (1968). Recall of full and truncated passive sentences in connected discourse. Journal of Verbal Learning and Verbal Behavior, 7, 876-881.

Spoehr, K. T., Morris, M. E., & Smith, E. E. (1984). Comprehension of Instructions for Operating Devices. (Technical Report No. 5712), Cambridge, Mass.: Bolt Beranek and Newman, Inc.

Sticht, T. G. (1977). Comprehending reading at work. In M. Just & P. Carpenter (Eds.), Cognitive processes in comprehension. Hillsdale, N. J.: Lawrence Erlbaum Associates.

Swarts, H., Flower, L. S., & Hayes, J. R. (1980). How headings in documents can mislead readers (Document Design Project Technical Report No. 9). Carnegie-Mellon University.

Tannenbaum, P. H., & Williams, F. (1968). Generation of active and passive sentences as a function of subject or object focus. Journal of Verbal Learning and Verbal Behavior, 7, 246-250.

Townsend, D. J., Ottaviano, D., & Bever, T. G. (1979). Immediate memory for words from main and subordinate clauses at different age levels. Journal of Psycholinguistic Research, 8, 83-101.

Turner, E. A. & Rommetveit, R. (1968). Focus of attention in recall of active and passive sentences. Journal of Verbal Learning and Verbal Behavior, 7, 543-548.

Vazquez, C. A. (1981). Sentence processing: Evidence against the serial, independent stage assumption. Journal of Psycholinguistic Research, 10, 363-374.

Villiers de, P. A. (1974). Imagery and theme in recall of connected discourse. Journal of Experimental Psychology, 103, 263-268.

Walker, N., Jones, P J., & Mar, H. H. (1983). Encoding processes and the recall of text. Memory and Cognition, 11, 275-282.

Wang, Marilyn D. (1970). The role of syntactic complexity as a determiner of comprehensibility. Journal of Verbal Learning and Verbal Behavior, 9, 398-404.

Waryas, C., & Stremel, K. (1974). On the preferred form of the double object construction. Journal of Psycholinguistic Research, 3, 271-280.

Wearing, A. J. (1970). The storage of complex sentences. Journal of Verbal Learning and Verbal Behavior, 9, 21-29.

Wisher, R. A. (1976). The effects of syntactic expectations during reading. Journal of Educational Psychology, 68, 597-602.

Yekovich, F. R., & Manelis, L. (1980). Accessing integrated and nonintegrated propositional structures in memory. Memory and Cognition, 8, 133-140.

Yekovich, F. R., & Walker, C. H. (1978). Identifying and using referents in sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 17, 265-278.

Yekovich, F. R., Walker, C. H., & Blackman, H. S. (1979). The role of presupposed and focal information in integrating sentences. Journal of Verbal Learning and Verbal Behavior, 18, 535-548.

APPENDIX

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Navy

1 Robert Ahlers
Code N711
Human Factors Laboratory
NAVTRAEQUIPCEN
Orlando, FL 32813

1 Dr. Ed Aiken
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Meryl S. Baker
Navy Personnel R&D Center
San Diego, CA 92152

1 CDR Robert J. Biersner, USN
Naval Biodynamics Laboratory
P. O. Box 29407
New Orleans , LA 70189

1 Dr. Alvah Bittner
Naval Biodynamics Laboratory
New Orleans, LA 70189

1 Code N711
Attn: Arthur S. Blaiwes
Naval Training Equipment Center
Orlando, FL 32813

1 Dr. Robert Blanchard
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Nick Bond
Office of Naval Research
Liaison Office, Far East
APO San Francisco, CA 96503

1 Lt. Alexander Bory
Applied Psychology
Measurement Division
NAMRL
NAS Pensacola, FL 32508

1 Dr. Richard Braby
TAEG
Naval Training Equipment Center
Orlando, FL 32813

1 Dr. Robert Breaux
NAVTRAEQUIPCEN
Code N-095R
Orlando, FL 32813

Navy

1 Dr. Richard Cantone
Navy Research Laboratory
Code 7510
Washington, DC 20375

1 Dr. Robert Carroll
NAVOP 115
Washington , DC 20370

1 Dr. Fred Chang
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Susan Chipman
Code 442PT
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 Chief of Naval Education and Training
Liason Office
Air Force Human Resource Laboratory
Operations Training Division
WILLIAMS AFB, AZ 85224

1 Dr. Stanley Collyer
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217

1 CDR Mike Curran
Office of Naval Research
800 N. Quincy St.
Code 270
Arlington, VA 22217

1 Dr. Charles E. Davis
Personnel and Training Research
Office of Naval Research (Code 442PT)
800 North Quincy Street
Arlington, VA 22217

1 Edward E. Eddowes
CNATRA N301
Naval Air Station
Corpus Christi, TX 78419

1 Dr. John Ellis
Navy Personnel R&D Center
San Diego, CA 92252

Navy

1 Dr. Richard Elster
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Carl E. Englund
Naval Health Research Center
Code 8060 Environmental Physiology Dept
P.O. Box 85122
San Diego, CA 92138

1 Dr. Marshall J. Farr
2520 North Vernon Street
Arlington, VA 22207

1 DR. PAT FEDERICO
Code P13
NPRDC
San Diego, CA 92152

1 Dr. Cathy Fernandes
Navy Personnel R&D Center
San Diego, CA 92152

1 Mr. Paul Foley
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Jude Franklin
Code 7510
Navy Research Laboratory
Washington, DC 20375

1 LT Steven D. Harris, MSC, USN
RFD 1, Box 243
Riner, VA 24149

1 Ms. Rebecca Hetter
Navy Personnel R&D Center (Code 62)
San Diego, CA 92152

1 Dr. Jim Hollan
Code 51
Navy Personnel R & D Center
San Diego, CA 92152

1 Mr. Dick Hoshaw
NAVOP-135
Arlington Annex
Room 2834
Washington , DC 20350

Navy

1 Dr. Ed Hutchins
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Norman J. Kerr
Chief of Naval Education and Training
Code 00A2
Naval Air Station
Pensacola, FL 32508

1 Dr. Peter Kincaid
Training Analysis & Evaluation Group
Dept. of the Navy
Orlando, FL 32813

1 Dr. Leonard Kroeker
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. David R. Lambert
C3EW Systems & Technology Dept.
Naval Ocean Systems Center
San Diego, CA 92152

1 Dr. Daryll Lang
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. William L. Maloy (02)
Chief of Naval Education and Training
Naval Air Station
Pensacola, FL 32508

1 Dr. Kneale Marshall
Chairman, Operations Research Dept.
Naval Post Graduate School
Monterey, CA 93940

1 Dr. James McBride
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Barbara McDonald
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Joe McLachlan
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. James McMichael
Navy PersonnelR&D Center
San Diego, CA 92152

Navy

1 Dr. Al Meyrowitz
Office of Naval Research
Code 433
800 N. Quincy
Arlington, VA 22217

1 Dr William Montague
NPRDC Code 13
San Diego, CA 92152

1 Ms. Kathleen Moreno
Navy Personnel R&D Center (Code 62)
San Diego, CA 92152

1 Library, Code P201L
Navy Personnel R&D Center
San Diego, CA 92152

1 Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390

1 Office of Naval Research
Code 433
800 N. Quincy SStreet
Arlington, VA 22217

1 Office of Naval Research
Code 441NP
800 N. Quincy Street
Arlington, VA 22217

1 Psychological Sciences Division
Code 442
Office of Naval Research
Arlington, VA 22217

1 Director
Engineering Psychology Program
Code 442EP
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

1 Organizational Effectiveness
Research Program, Code 442OE
Office of Naval Research
Arlington, VA 22217

Navy

6 Personnel & Training Research Program
Code 442PT
Office of Naval Research
Arlington, VA 22217

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Office of the Chief of Naval Operations
Research Development & Studies Branch
OP 115
Washington, DC 20350

1 Daira Paulson
Code 52 - Training Systems
Navy Personnel R&D Center
San Diego, CA 92152

1 LT Frank C. Petho, MSC, USN (Ph.D)
CNET (N-432)
NAS
Pensacola, FL 32508

1 Dr. Gary Poock
Operations Research Department
Code 55PK
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Gil Ricard
Code N711
NTEC
Orlando, FL 32813

1 Dr. Bernard Rimland
Navy Personnel R&D Center
San Diego, CA 92152

1 William Rizzo
Code 712 NTEC
Orlando, FL 32813

1 Dr. Carl Ross
CNET-PDCD
Building 90
Great Lakes NTC, IL 60088

Navy

1 Dr. F. E. Saalfeld
Director, Research Programs
Code 400
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 Mr. Drew Sands
NPRDC Code 62
San Diego, CA 92152

1 Lt. Marybeth Schnable
COMNAVCRUITCOM
Code 215
4015 Wilson Blvd
Arlington, VA 22206

1 Dr. Paul B. Schneck
Office of Naval Research
Code 433
800 N. Quincy
Arlington, VA 22217

1 Dr. Mary Schratz
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Michael G. Shafto
ONR Code 442PT
800 N. Quincy Street
Arlington, VA 22217

1 Dr. Robert Smillie
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Alfred F. Smode
Senior Scientist
Code 7B
Naval Training Equipment Center
Orlando, FL 32813

1 Dr. Richard Snow
Liaison Scientist
Office of Naval Research
Branch Office, London
Box 39
FPO New York, NY 09510

1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152

Navy

1 Dr. Thomas Sticht
Navy Personnel R&D Center
San Diego, CA 92152

1 Mr. Brad Sympson
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Martin A. Tolcott
Leader, Psychological Sciences Division
Office of Naval Research
800 N. Quincy St.
Arlinsgon, VA 22217

1 Dr. James Tweeddale
Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Frank Vicino
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Edward Wegman
Office of Naval Research (Code 411S&P)
800 North Quincy Street
Arlington, VA 22217

1 Roger Weissinger-Baylon
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Ronald Weitzman
Naval Postgraduate School
Department of Administrative
Sciences
Monterey, CA 93940

1 Dr. Douglas Wetzel
Code 12
Navy Personnel R&D Center
San Diego, CA 92152

1 DR. MARTIN F. WISKOFF
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

1 Mr John H. Wolfe
Navy Personnel R&D Center
San Diego, CA 92152

Navy

1 Dr. Donald Woodward
Office of Naval Research (Code 441)
800 North Quincy Street
Arlington, VA 22217

1 Dr. Wallace Wulfeck, III
Navy Personnel R&D Center
San Diego, CA 92152

1 Capt. Bruce Young
COMNAVCRUITCOM
Code 21
4015 Wilson Blvd
Arlington, VA 22206

1 Cmdr. Joe Young
HQ. MEPCOM
ATTN: MEPCT-P
2500 Green Bay Road
North Chicago, IL 60064

1 Dr. Steven Zornetzer
Associate Director for Life Sciences
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

Marine Corps

1 Capt. Rick Butler
CAT Project Office
HQ, Marine Corps
Washington, DC 20380

1 Mr. Paul DiRenzo
Commandant of the Marine Corps
Code LEC-4
Washington, DC 20380

1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 Maj. John Keene
ADP Systems Branch
C3 Development Center (D104)
MCDEC
Quantico , VA 22134

1 Col. Ray Leidich
Headquarters, Marine Corps
MPI
Washington, DC 20380

1 Headquarters, U. S. Marine Corps
Code MPI-20
Washington, DC 20380

1 Lt. Col. Jim Murphy
HQ, Marine Corps
Code MRRP
Washington, DC 20380

1 Special Assistant for Marine
Corps Matters
Code 100M
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

1 Dr. Sydell Weiss
Headquarters, USMC
Code TDE 22
Rm 2301
Navy Annex
Washington, DC 20380

Marine Corps

1 Major Frank Yohannan, USMC
Headquarters, Marine Corps
(Code MPI-20)
Washington, DC 20380

Army

1 Technical Director
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Mr. J. Barber
HQS, Department of the Army
DAPE-ZER
Washington, DC 20310

1 Dr. Kent Eaton
Army Research Institute
5001 Eisenhower Blvd.
Alexandria , VA 22333

1 Lt. Col Rich Entlich
HQ, Dept. of the Army
OCSA(DACS-DPM)
Washington, DC 20310

1 Dr. Beatrice J. Farr
U. S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Myron Fischl
U.S. Army Research Institute for the
Social and Behavioral Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Donald Haggard
Fort Knox Field Unit
Army Research Institute
Steele Hall
Ft. Knox, KY 40121

1 Lt. Col. Ron Harmer
USARCRO-RS
Ft. Sheridan, IL 60037

1 Chief, ARI Field Unit
P. O. Box 5787
Presidio of Monterey
Monterey, CA 93944

1 Dr. Milton S. Katz
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Army

1 Dr. Clessen Martin
Army Research Institute
5001 Eisenhower Blvd.
Alexandria, VA 22333

1 Dr. Karen Mitchell
Army Research Institute
5001 Eisenhower Blvd
Alexandria, VA 22333

1 Dr. William E. Nordbrock
FMC-ADCO Box 25
APO, NY 09710

1 Dr. Harold F. O'Neil, Jr.
Director, Training Research Lab
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Commander, U.S. Army Research Institute
for the Behavioral & Social Sciences
ATTN: PERI-BR (Dr. Judith Orasanu)
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Ray Perez
5001 Eisenhower Avenue
PERI-II
Alexandria, VA 22333

1 Joseph Psotka, Ph.D.
ATTN: PERI-IC
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

1 Mr. Robert Ross
U.S. Army Research Institute for the
Social and Behavioral Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Mr. Lou Ruberton
DAPE-MPA-C3
Department of the Army
Washington, DC 20310

1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

Army

1 DR. ROBERT J. SEIDEL
US Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

1 Dr. Joyce Shields
Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Zita M. Simutis
Chief, Instructional Technology
Systems Area
ARI
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Ms. Betty Stickel
DAPE-MPA-P
2B729 Pentagon
Washington, DC 20310

1 Dr. Hilda Wing
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

Air Force

1 Air Force Human Resources Lab
AFHRL/MPD
Brooks AFB, TX 78235

1 U.S. Air Force Office of Scientific Research
Life Sciences Directorate, NL
Bolling Air Force Base
Washington, DC 20332

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235

1 Col. Roger Campbell
AF/MPXOA
Pentagon, Room 4E195
Washington, DC 20330

1 Mr. Raymond E. Christal
AFHRL/MOE
Brooks AFB, TX 78235

1 Bryan Dallman
AFHRL/LRT
Lowry AFB, CO 80230

1 Mr. Robert Denton
AFMPC/MPCYPR
Randolph AFB, TX 78150

1 Dr. Alfred R. Fregly
AFOSR/NL
Bolling AFB, DC 20332

1 Dr. Thomas Killion
UDRI
P. O. Box 44
Higley, AZ 85236

1 Dr. Patrick Kyllonen
AFHRL/MOE

Brooks AFB, TX 78235

1 Dr. T. M. Longridge
AFHRL/OTE
Williams AFB, AZ 85224

1 Dr. Sylvia R. Mayer (TOIT)
HQ Electronic Systems Division
Hanscom AFB
Bedord, MA 02173

Air Force

1 Dr. Randolph Park
AFHRL/MOAN
Brooks AFB, TX 78235

1 Dr. Roger Pennell
Air Force Human Resources Laboratory
Lowry AFB, CO 80230

1 Dr. Malcolm Ree
AFHRL/MP
Brooks AFB, TX 78235

1 Dr. Lawrence E. Reed
Research Psychologist
AFHRL/LRG
Wright-
Patterson AFB
, OH 45433

1 Dr. Sam Schiflett
USAFAM/VNB
Brooks AFB, TX 78235

1 Maj. Bill Strickland
AF/MPXOA
4E168 Pentagon
Washington, DC 20330

1 Dr. John Tangney
AFOSR/NL
Bolling AFB, DC 20332

1 Lt. Col James E. Watson
HQ USAF/MPXOA
The Pentagon
Washington, DC 20330

1 Major John Welsh
AFHRL/MOAN
Brooks AFB , TX 78223

1 Dr. Joseph Yasatuke
AFHRL/LRT
Lowry AFB, CO 80230

Department of Defense

1 Mr. Bob Brandewie
Defense Manpower Data Center
550 Camino El Estisro, #200
Monterey, CA 93940

1 Mr. J. Burgener
MEPCOM
MEPCT-P
2500 Green Bay Road
North Chicago, IL 60064

1 Dr. Dennis Bybee
Computer Education Coordinator
DoD Dependant Schools
2461 Eisenhower Avenue
Room 172
Alexandria, VA 22331

1 LCmdr. Tom Dean
HQ. MEPCOM
MEPCAM-P
2500 Green Bay Road
North Chicago , IL 60064

12 Defense Technical Information Center
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC

1 Dr. Craig I. Fields
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

1 Jordan Grafman, Ph.D.
Department of Clinical Investigation
Walter Reed Army Medical Center
6825 Georgia Ave., N. W.
Washington, DC 20307

1 Dr. Anita Lancaster
Accession Policy
OASD/MI&L/MP&FM/AP
Pentagon, Room 2B271
Washington, DC 20301

1 Dr. Jerry Lehnus
OASD (M&RA)
Washington , DC 20301

Department of Defense

1 Dr. Clarence McCormick
HQ, MEPCOM
MEPCT-P
2500 Green Bay Road
Noprth Chicago, IL 60064

1 Military Assistant for Training and
Personnel Technology
Office of the Under Secretary of Defens
for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

1 Col. Van Poznak
HQ, MEPCOM
ATTN: Director MEPCAM
2500 Green Bay Road
North Chicago, IL 60064

1 Dr. W. Steve Sellman
Office of the Assistant Secretary
of Defense (MRA & L)
2B269 The Pentagon
Washington, DC 20301

1 Mr. John Stryker
HQ, MEPCOM
MEPCAM
2500 Green Bay Road
North Chicago, IL 60064

1 Major Jack Thorpe
DARPA
1400 Wilson Blvd.
Arlington, VA 22209

1 Dr. Robert A. Wisher
U.S. Army Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria , VA 22333

Civilian Agencies

1 Mr. Jim Carey
Coast Guard G-PTE
2100 Second St., S.W.
Washington, DC 20593

1 Edward Esty
Department of Education, OERI
MS 40
1200 19th St., NW
Washington, DC 20208

1 Dr. Arthur Melmed
724 Brown
U. S. Dept. of Education
Washington, DC 20208

1 Dr. Andrew R. Molnar
Office of Scientific and Engineering
Personnel and Education
National Science Foundation
Washington, DC 20550

1 Dr. Judy Segal
NIE
1200 19th Street N.W.
Mail Stop 6
Washington, DC 20208

1 Dr. Frederick Steinheiser
CIA-ORD
612 Ames
Washington, DC 20505

1 Dr. Frank Withrow
U. S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202

1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Private Sector

1 Dr. John R. Anderson
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Patricia Baggett
Department of Psychology
University of Colorado
Boulder, CO 80309

1 Eva L. Baker
Director
UCLA Center for the Study of Evaluation
145 Moore Hall
University of California, Los Angeles
Los Angeles, CA 90024

1 Dr. John Black
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. John S. Brown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304

1 Dr. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. Davida Charney
Department of Psychology
Carnegie-Melon University
Schneley Park
Pittsburgh, PA 15213

1 Eugene Charniak
Department of Computer Science
Brown University
Providence, RI 02912

1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Thomas M. Duffy
Department of English
Carnegie-Mellon University
Schenley Park
Pittsburgh, CA 15213

Private Sector

1 Dr. Anders Ericsson
Department of Psychology
University of Colorado
Boulder, CO 80309

1 Mr. Wallace Feurzeig
Department of Educational Technology
Bolt Beranek & Newman
10 Moulton St.
Cambridge, MA 02238

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Dedre Gentner
University of Illinois
Department of Psychology
Urbana , IL

1 Dr. Robert Glaser
Learning Research & Development Center
University of Pittsburgh
3939 O'Hara Street
PITTSBURGH, PA 15260

1 Dr. Marvin D. Glock
217 Stone Hall
Cornell University
Ithaca, NY 14853

1 Dr. Josph Goguen
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

1 Dr. Henry M. Halff
Halff Resources
4918 33rd Road, North
Arlington, VA 22207

1 Dr. Reid Hastie
Department of Psychology
Northwestern University
Evanston, IL 60201

1 Dr. Joan I. Heller
Graduate Group in Science and
Mathematics Education
c/o School of Education
University of California
Berkeley, CA 94720

Private Sector

1 Melissa Holland
American Institutes for Research
1055 Thomas Jefferson St., N.W.
Washington, DC 20007

1 Dr. Marcel Just
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. David Kieras
Program in Technical Communication
College of Engineering
1223 E. Engineering Building
University of Michigan
Ann Arbor, MI 48109

1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302

1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

1 Dr. Don Lyon
P. O. Box 44
Higley , AZ 85236

1 Dr. Jay McClelland
Department of Psychology
MIT
Cambridge, MA 02139

1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277

1 Dr. Donald A Norman
Cognitive Science, C-015
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Nancy Pennington
University of Chicago
Graduate School of Business
1101 E. 58th St.
Chicago, IL 60637

Private Sector

1 Dr. Tjeerd Plomp
Twente University of Technology
Dept. of Education
7500 AE ENSCHEDE
P.O. Box 217
THE NETHERLANDS

1 Dr. Steven E. Poltrock
MCC
9430 Research Blvd.
Echelon Bldg #1
Austin , TX 78759

1 Dr. Lynne Reder
Department of Psychology
Carnegie-Mellon University
Schenley Park
Pittsburgh, PA 15213

1 Dr. Lauren Resnick
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 1521

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

1 Dr. Roger Schank
Yale University
Department of Computer Science
P.O. Box 2158
New Haven, CT 06520

1 Dr. Edward E. Smith
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Kathryn T. Spoehr
Psychology Department
Brown University
Providence, RI 02912

1 James J. Staszewski
Research Associate
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

Private Sector

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Albert Stevens
Bolt Beranek & Newman, Inc.
10 Moulton St.
Cambridge, MA 02238

1 Dr. David Stone
KAJ Software, Inc.
3420 East Shea Blvd.
Suite 161
Pheonix, AZ 85028

1 Beth Warren
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

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