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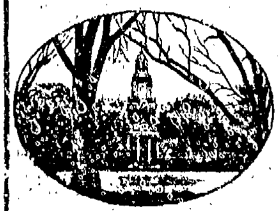

DEPARTMENT OF PSYCHOLOGY

TECHNICAL REPORT – 5

INTERACTIVE HUMAN COMMUNICATION: SOME LESSONS LEARNED FROM LABORATORY EXPERIMENTS

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The paper summarizes the principal findings of eleven different experiments from a research program on interactive communication. Among the principal findings are that: (1) Modes of communication having a voice channel are faster, but much wordier, than those that do not have a voice channel. (2) Face-to-face communication is not appreciably faster, and is generally wordier, than communication by voice alone. (3) Typing skill per se does

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) not appear to be a significant factor in the kind of communication examined in these studies. (4) Giving communicators the freedom to interrupt has no effect on problem solution time or on the number of words used. When communicators have the freedom to interrupt, they use more messages and messages are shorter. When they cannot interrupt, they use fewer messages and messages are longer. (5) Communicators are much more likely to take control of a communication system if the system has a voice channel. (6) In many realistic tasks, communicators spend as much as 50% of their time in activities other than communicating. (7) College students and high school students do about the same kinds of things in communication tasks, and in the same proportions. However, college students do everything faster. (8) Communicators in teletype modes are more likely to share equally in the exchange of information than in modes that have a voice channel. (9) Natural human communication is extremely unruly and often seems to follow few grammatical, syntactic, or semantic rules. (10) Oral communication is highly redundant and most communication can be carried on effectively with a small, carefully selected set of words.

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INTERACTIVE HUMAN COMMUNICATION:

Some Lessons Learned from Laboratory Experiments

By

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Paper presented at a
NATO Advanced Study Institute on
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This paper describes some findings that have come out of my research program on interactive communication. Altogether my colleagues, my students, and I have completed 11 separate experiments and have published eight articles based on those experiments (Chapanis, 1971; Chapanis, 1973; Chapanis, 1975; Chapanis, Ochsman, Parrish, and Weeks, 1972; Chapanis and Overbey, 1974; Ochsman and Chapanis, 1974; Weeks and Chapanis, 1976; and Weeks, Kelly, and Chapanis, 1974). Two additional articles are in press (Chapanis, Parrish, Ochsman, and Weeks, 1976; and Stoll, Hoecker, Krueger, and Chapanis, 1976) and two experiments have been reported as doctoral dissertations (Kelly, 1976; and Parrish, 1974). At the time this paper was prepared, several other articles were in various stages of preparation.

In discussing the findings of my own research program, I do not mean to suggest that it is the only one that has been concerned with these problems. A great deal of very good work on person-to-person communication, and on man-computer communication, has been done in other laboratories. Prominent among the former are the Communications Studies Group at University College London, Bell Laboratories in the United States, Carleton University in Canada, and Bell Northern Research in Canada. The Massachusetts Institute of Technology, RAND Corporation, Systems Development Corporation, International Business Machines Corporation, and Bolt, Beranek and Newman are just a few of the many organizations that have done excellent research on man-computer interactions. While acknowledging the fine work of those other laboratories, I have chosen to confine myself to my own program for two largely selfish reasons: (a) This is the first opportunity I have had to summarize and integrate our findings to date. (b) My research program has some rather unique features that are not duplicated in any other research programs that I know about.

The goals of my research program are to discover (a) how people naturally communicate with each other when they are required to solve problems of various kinds, (b) how interactive human communication is affected by the machine devices and systems through which people converse, and (c) what significant system and human variables affect interactive communication.

Interactive Communication Defined

In communication research it is important to make a distinction between interactive and unidirectional communication. For years psychologists and other scientists have been concerned with the effectiveness of unidirectional modes of communication, such as highway signs, books, lectures, and television broadcasts. In unidirectional communication, the person to whom a message is addressed is a passive recipient of information. Nothing that he does or says affects the communicator, the communication process, or the content of a message.

In interactive communication, by contrast, the participants are both senders and receivers of information. Communicators, the communication process, and the contents of messages can be, and usually are, affected by all the participants. Conferences, arguments, seminars, telephone conversations, and man-computer dialogs are examples of interactive communication. This paper is entirely concerned with interactive communication.

Man-Computer Dialog and its Relation to Interactive Human Communication

The research I shall talk about was done entirely by having people communicate with one another. In only one of our experiments did we actually use a computer in the communication process (Kelly, 1976) and then the computer was used only to assure that messages conform to certain constraints of vocabulary and grammar. That being the case, one might well ask what the findings of my research program have to do with man-computer communication.

Although people do not resemble computers at all physically, some of the things they both do are sufficiently similar that computers have been called "giant brains" (Berkeley, 1949). The similarities become even more striking when we compare person-to-person telecommunications with man-computer communications. In the first place, the interactions between man and modern computers may, in a manner of speaking, be thought of as conversations. They are characterized by commands, statements, questions, answers to questions, and sundry other messages that go from man to computer and vice versa. As may be apparent, these exchanges are truly interactive in the sense that I have been using the word.

Conversations between people and computers are all carried out in one of several different languages which, although they are not exactly colloquial English, are close enough to it so that the language can be recognized and learned more or less readily. To be sure, the input options for communications from man to computer are still limited to typewritten materials, some simple and highly constrained forms of cursor-positioning and handwriting and a few primitive voice signals. On the other hand, output devices that carry communications from computers to man cover the full range of those that one finds in person-to-person telecommunication systems--printed materials, voice, graphics and pictures. Most impressive of all, however, is that some computer programs have been made so human-like that people who have used the systems have actually been misled--at least for a time--into believing that they were communicating with another person! (Weizenbaum, 1970)

The essential unity of communication problems, whether they be with other people or with computers, is the basis for my belief that a complete understanding of person-to-person communication is essential to a proper understanding of how best to design computers for effective man-computer dialogs.

I also believe that the future will see an integration of communication systems that we now think of as separate. Indeed, computers have already been combined with person-to-person telecommunication systems in computer conferencing, a written form of conference telephone calls ("The Future of Computer Conferencing," 1975). At a more sophisticated level, Vannevar Bush's visionary article, "As We May Think" (1945), first called attention to the extraordinary power that modern computers have to supplement human cognitive functions. Bush saw the computer as providing an enlarged intimate adjunct to a user's memory. "Associative trails," much like the associations that characterize human thinking, would make it possible to bring the enormous capacity of modern computers to integrate, file, sort, and compile the contents of encyclopedias, books, newspapers, letters, opinions, and human experiences.

Bush's article was, of course, far ahead of the technology of that time. A similar and more recent endeavor is Licklider's (1965) treatment of Libraries of the Future which foresaw the revolution in library systems now beginning to appear in such forms as the New York Times Information Bank.

Combine such a computer system with person-to-person telecommunication systems and the product will be a truly all-purpose information system. With it one will be able to:

- o Exchange messages and "letters" with other people and with computers
- o Hold teleconferences
- o Do computations
- o Jointly write and edit articles and journals
- o Collect files of important documents
- o Search files
- o Keep personal diaries
- o Design and write specifications for new equipment and systems
- o Teach classes
- o Conduct interviews
- o Perform all manner of banking transactions
- o Order groceries, theater tickets, and equipment

And the list could go on and on.

One of the most important characteristics of such advanced systems is that all these activities would be independent of time and space. Conferences, interviews, classes, and other interactions could be carried out among persons in widely separated places on the earth, as easily as they could be conducted next door. Even more important is that such systems would make it possible to draw upon the collective intelligences of man and computer. Indeed, one can easily imagine that the contributions of man and computer would be so commingled that one would never be sure whether a thought, idea, suggestion, or solution, came from a man or computer.

To make that kind of dream reality will require a great deal of imaginative and careful research on the ways in which telecommunication and computer technologies can be most effectively married to satisfy their ultimate users. Only after we have done that research will we be able to achieve the complete "man-computer symbiosis" that was so confidently predicted nearly two decades ago (Licklider, 1960), but that has remained so elusively and so tantalizingly beyond our grasp.

The research I shall talk about provides a few answers about how people communicate with each other interactively and about some of the variables that affect those communications. The lessons to be learned from that research are, in my opinion, just as useful in the design of computer systems as in the design of person-to-person telecommunication systems. In thinking about my research and its implications for computer systems, however, I prefer not to confine myself to any particular computer system, or to computer systems as they are today. For example, some computers today can receive voice signals from a very limited and highly constrained repertory. Similarly, a few computer systems can accept some highly constrained forms of hand drawn letters and numerals. These are only limitations of our current technology. I prefer not to be bound by such limitations. I am much more concerned with what we need to know to build highly versatile, flexible, and adaptive computers of the kind that exist only in our imaginations today, but that will certainly become realities at some time in the future. In considering the findings that I shall describe here, I invite you to join me in adopting that kind of long-range perspective.

Modes of Person-to-Person and Man-Computer Communication Compared

In considering modes of communication it is interesting to ask first what human skills are used naturally in person-to-person communication. The list is surprisingly short. Everyone, even the inarticulate and dumb, can convey information by body movements--postures, gestures, and facial expressions. Virtually everyone can speak one of the natural languages--perhaps not grammatically, but fluently. A majority of people have at least some elementary level of competence in writing. Finally, a respectable number of people know how to type and even some people without typing experience seem to be able to approach the keyboard and peck out acceptable messages. But these few different kinds of skills exhaust the list.

That very same list of skills is a catalog of the principal ways in which people could conceivably communicate with computers. Note, however, that I mentioned these human communication skills in the order of easiest, or most universal, to hardest, or most specialized. Everyone can communicate by body movements, slightly fewer people can express themselves vocally, still fewer people can communicate by handwriting and typing is the least widely available human communicative skill. That order is exactly the reverse of their adaptability to man-computer communication. Typewriting, the least universal mode of person-to-person communication, is easiest and most adaptable for man-computer communication. On the other hand, no one foresees body movements--the most universal mode of human communication--as a viable alternative for man-computer communication--even in the year 2,001.

The Research Setting and Laboratory

Our experiments have tested four different channels of communication that are the mechanical or electronic counterparts of the four forms of natural human communication that I have just described. The four channels are video (the picture part of television without the voice), voice, handwriting, and typewriting. Three of the four basic channels have been tested singly, and all of them have been tested in various combinations. The individual channels or combinations of them are referred to collectively as modes. We have tested as many as ten different modes in a single experiment (Ochsman and Chapanis, 1974). As a standard of comparison we typically rely on normal, unrestricted, face-to-face communication, which for several reasons, we have called a communication-rich mode.

The laboratory in which most of our experiments have been done consisted of two adjoining rooms connected by a soundproofed double door (Figure 1). The wall between the rooms also had in it a large double-glass panel, which could be covered with an opaque screen so that the persons in each of the rooms could not see each other. When the panel was not covered, the participants could see each other and could converse freely through a microphone and loudspeaker, even though they were separated physically. In some of our experiments, subjects have actually been face-to-face, or side by side, in the same room.

Figure 1 shows teletypewriting and telautograph machines. These machines are linked in such a way that anything typewritten or written in longhand on a machine in one room is simultaneously reproduced on the other. Video cameras and monitors enable us to duplicate closed-circuit television or to use either the video or audio channels separately.

About a year ago, we expanded and redesigned our laboratories as shown in Figure 2. The new arrangement permits us to test as many as four persons in as many different rooms. Communication facilities among the rooms allow all persons to communicate with all others, or allow only certain communication links to be used.

Problems

In our research we have tested two main kinds of problems: cooperative and conflictive. Altogether we have compiled and tested nearly 20 different problems of both kinds.

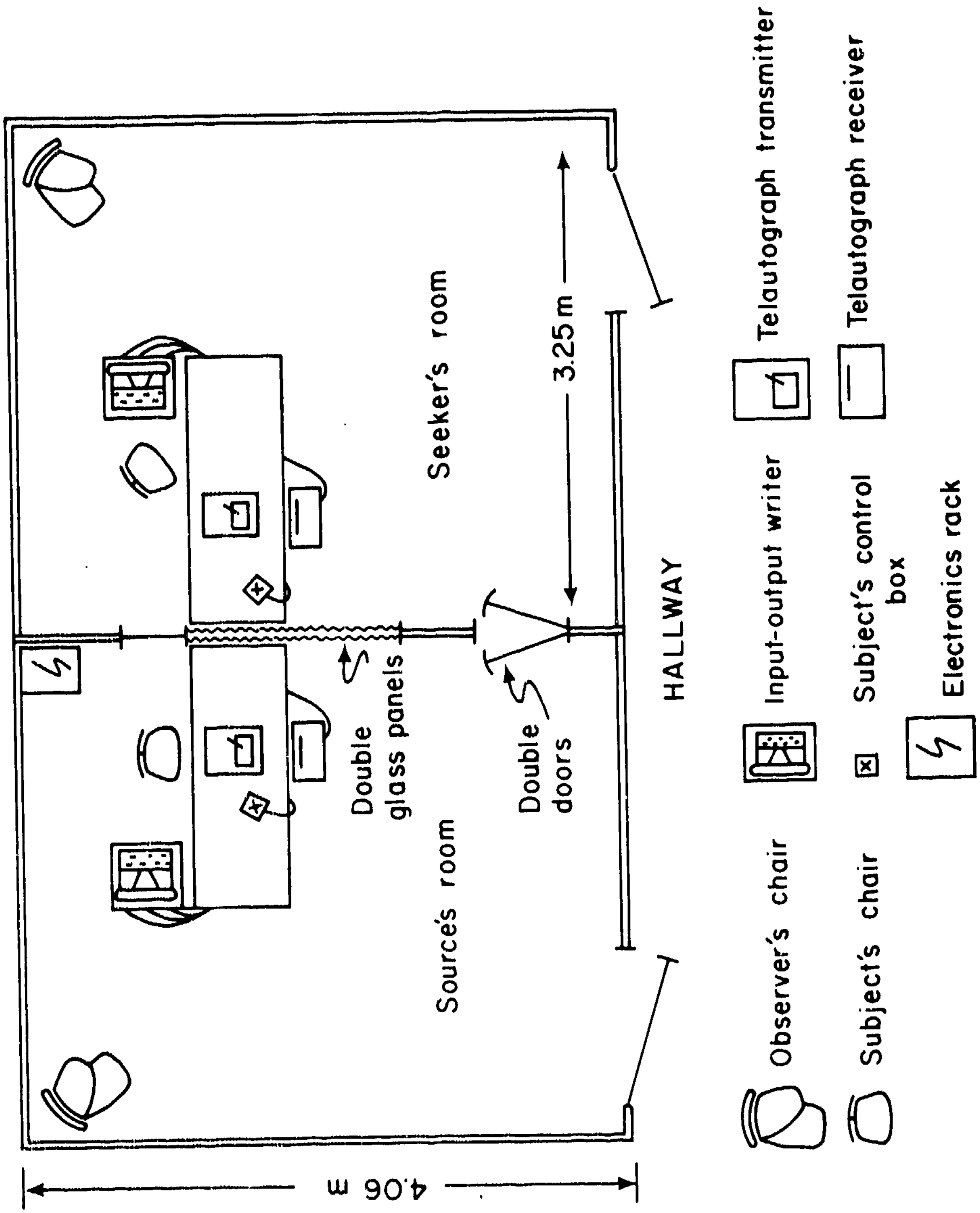


Fig. 1. The two experimental rooms and associated equipment used in most of our earlier work.

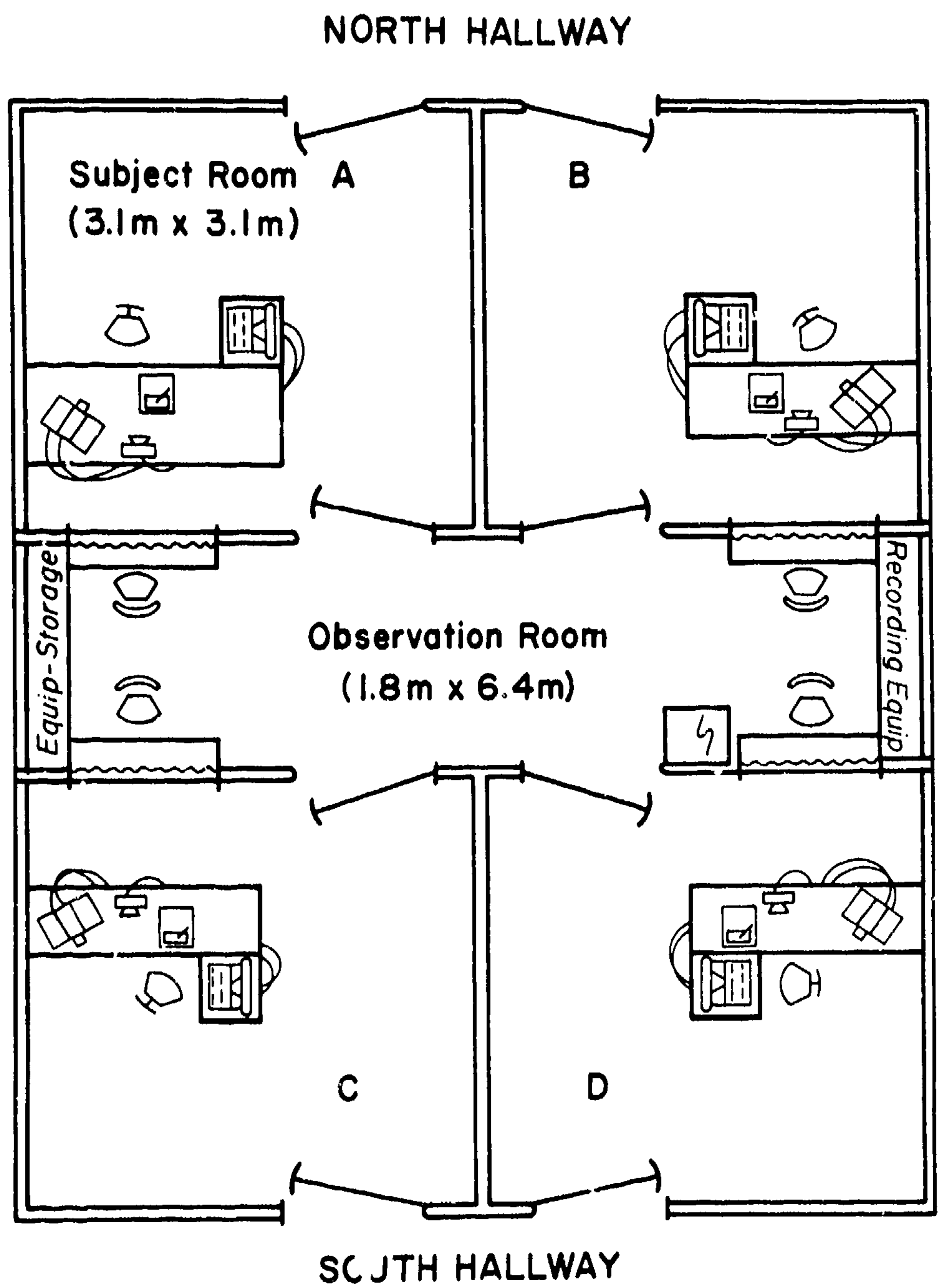
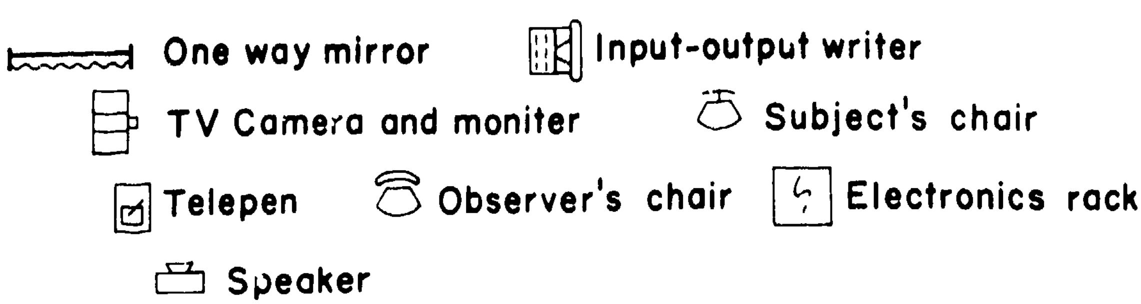


Fig. 2. The new communication laboratory at Johns Hopkins.



Cooperative Problems

Our cooperative problems have been carefully chosen to meet several important criteria:

1. The set of problems samples a wide range of psychological abilities. For example, some problems are entirely clerical paper-and-pencil tasks, some involve mechanical manipulation, others require careful attention to detail, and others make use of still other psychological skills.

2. The problems are representative of tasks for which interactive computer systems are currently being used, or might be used in the future.

3. They are of recognizable and practical importance in everyday life--they are not abstract or artificial problems of the type often constructed to measure hypothetical psychological processes.

4. They have definite, recognizable solutions and the solutions can be reached within approximately an hour.

5. They require few or essentially no specialized skills or specialized knowledge for their solution.

6. They are formulated in such a way that their solutions require the efforts of two individuals working together as a team. This is done by deliberately structuring the problems so that each member of a team receives complementary information folios. One member of the team, the seeker, is given a problem for which he has to find a solution. His information folio consists of certain parts of the problem. The other member of the team, the source, has a folio with the remainder of the information needed to solve the problem. Therefore, while neither person can solve the problem by himself, the two of them have all the information necessary to do so. Although the analogy will not survive careful scrutiny, I tend to think of the seeker as a person who comes to a computer with a problem, and the source as a perfect computer, that is, a computer so human-like in its responses that it would easily pass Turing's test (1950). I emphasize, however, that our problems are designed to elicit communication between the members of a team. Our division of the problems does not necessarily represent the way tasks would be allocated to man and computer in an actual system.

The brief descriptions of four of our problems below will convey some idea of their content, diversity, and flavor.

Wiring task. The seeker is given a digital logic panel (Figure 3) and some wires with clip ends. When the panel is correctly wired (Figure 4) and the power is turned on, the assembly counts digits in the binary system. Information about how to wire the panel is supplied by the source who has a correctly wired panel at the start.

Object identification task. The seeker is given a small electric light socket (Figure 5) and is asked to obtain an identical replacement socket from his partner. The source has a set of 65 different Leecraft pilot light sockets (Figure 6). Although all 65 sockets in the source's folio are similar to the seeker's in some respect, only one is a perfect match.

Class scheduling problem. The seeker is given a list of four college courses which have to be arranged into a workable schedule within specified time constraints, such as commuting schedules. The source has a 97-page booklet listing the complete time schedule for courses at the University of Maryland. The courses and constraints are such that there is only a single correct solution.

Information retrieval problem. The seeker is asked to prepare a bibliography of newspaper articles on a specific topic. The citations have to be drawn from the New York Times Index in the source's possession.

Conflictive Problems

Our conflictive problems are structured to provide a setting for argumentative discourse among communicators. The topical matter for discussion is chosen to be relevant to the subject population, yet is sufficiently general in nature that none of the participants is likely to have an inherent advantage by virtue of specialized experience. The problems are also designed to be used, and they have been used, with groups of more than two persons. Since there are no unique solutions to the problems, the subjects are left to debate the merits of alternative solutions in meeting certain criteria, and are required to arrive at a consensus or agreement. An example of each of two different kinds of conflictive problem follows:

National issues problem. The participants are asked to rank order the ten most important issues facing the United States today. An additional requirement is that the participants must rank order the issues, not as they think about them privately, but as they

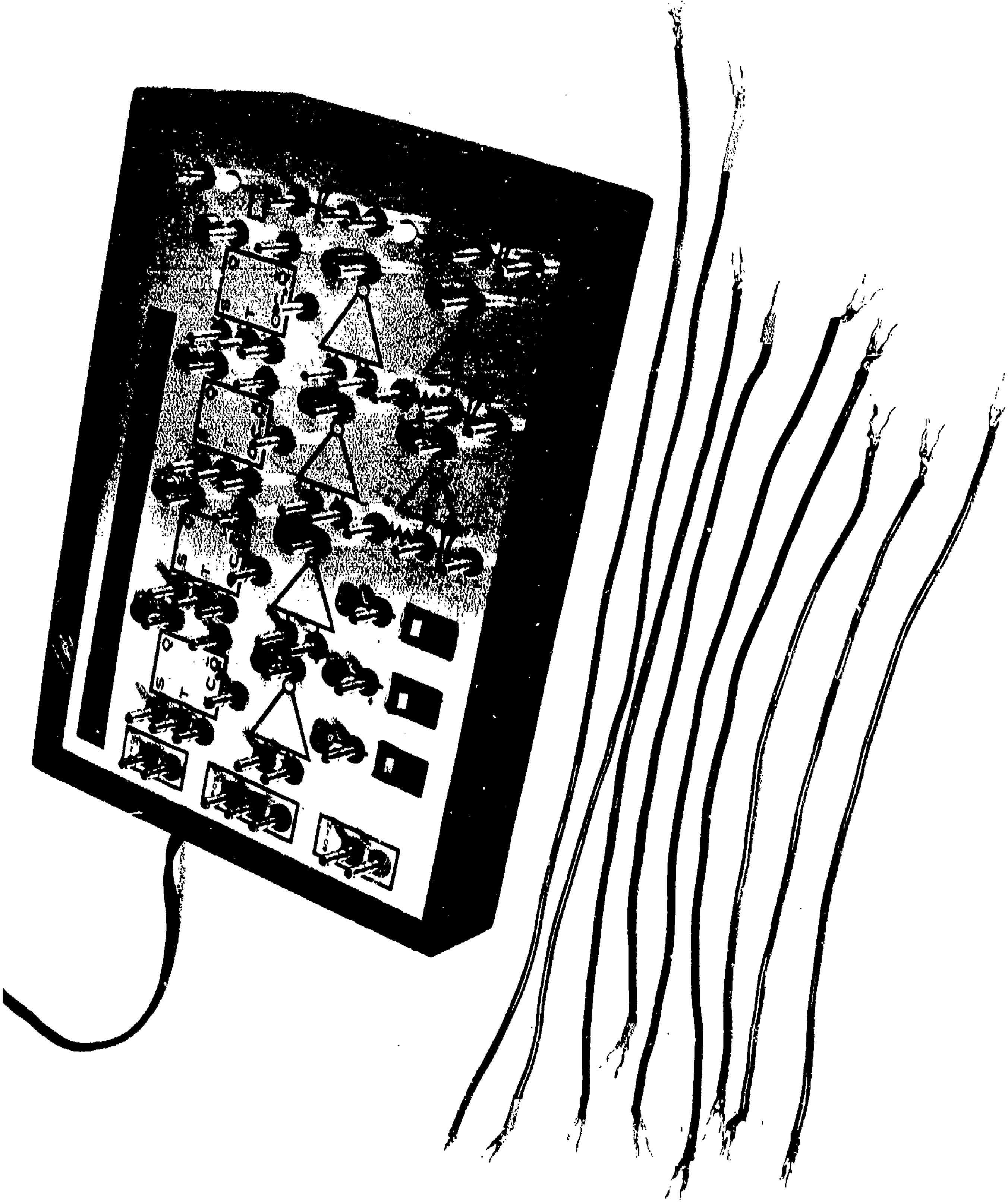


Fig. 3. A digital logic microlaboratory teaching device. This photograph does not show clearly the three different colors of connecting wires (below).

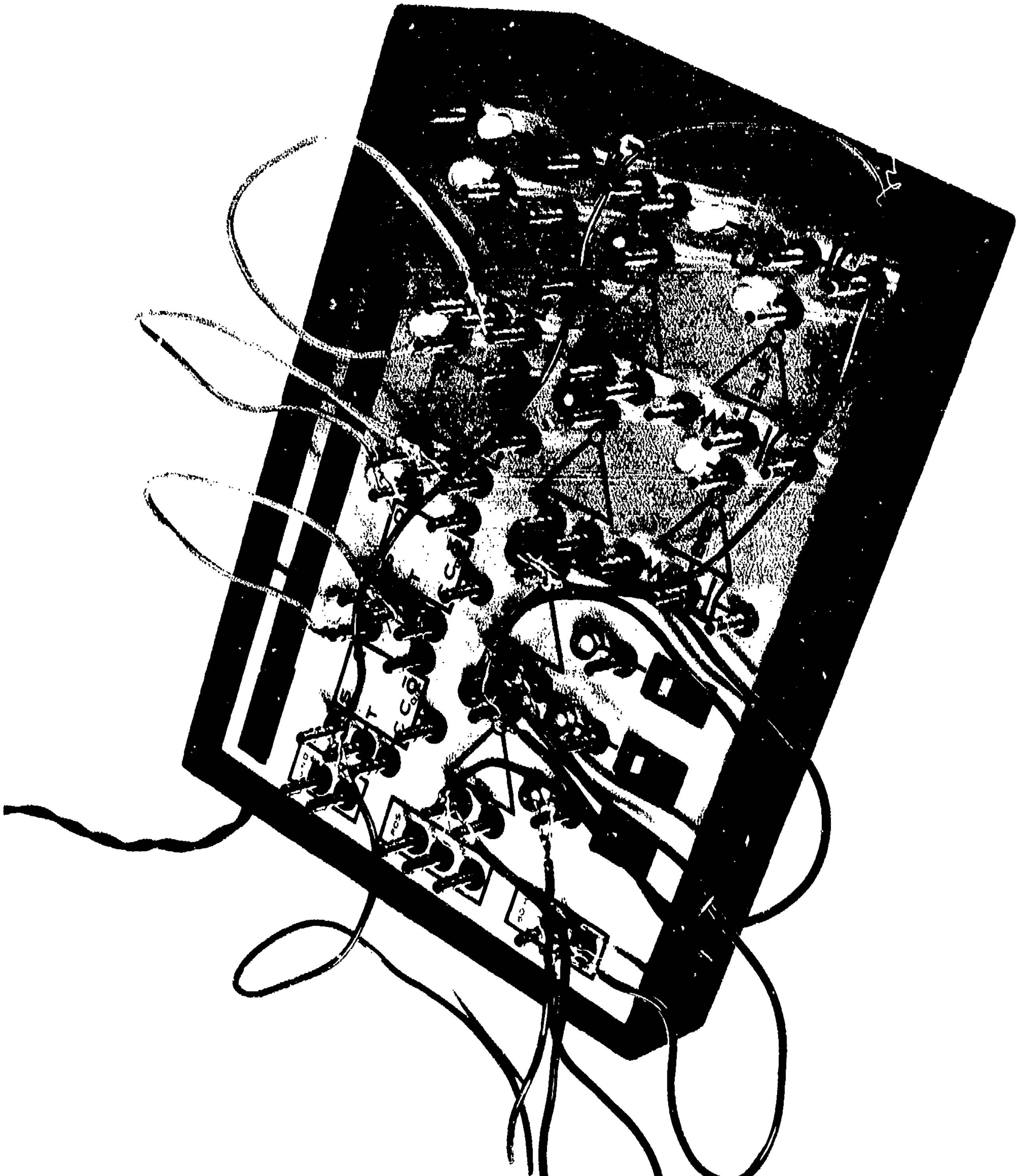


Fig. 4. When the device in Figure 3 is wired in this manner, the circui will count digits in the binary system.

Fig. 5. The electric light socket given the seeker at the start of the object identification problem.

Fig. 6. The set of light sockets given the source at the start of the object identification problem.

think the average undergraduate student had ranked them in a prior survey. The purposes of the latter requirement are to provide (a) an additional basis for argumentation, and (b) a basis for estimating the "goodness" of the solutions.

Budget-negotiation problem. We have several variations of a budget-negotiation problem. The following describes one that seems to generate a considerable amount of interest among our undergraduate students. The subjects are told that the University's Director of Athletics must reduce expenses in a number of different areas of expenditure, for example, uniforms and equipment, athletic scholarships, and travel. The subjects are cast in the role of captains of various teams, for example, football and lacrosse, and they have to agree on the areas in which budget cuts will be made. The payoffs for the different subjects are different so that a cut in expenditure for transportation for the football team is not equivalent to that for the lacrosse team. Each subject knows his own payoff structure but not that of the other participants. Each subject's goal is to minimize the losses to his side, that is, his team, and each subject's payment for participation in the experiment is reduced in proportion to the losses he sustains from the mutually-agreed upon solution to the problem.

Other Experimental Conditions

Without elaborating in detail, our experiments have been done on three different populations: High school boys, high school girls, and college students at Johns Hopkins. In some cases, subjects have been selected for particular intellectual abilities.

Most of our experiments have been done with two participants. Two, however, have been done with as many as four subjects. All our experiments have tested at least two different problems. In four experiments, subjects have been tested on as many as four successive days.

Results

Our results have been so numerous that it would be impossible to summarize them all here. Rather I shall discuss some of the more salient findings, particularly as they seem to bear on the problem of man-computer dialog. I shall also select data from a variety of different experiments without elaborating on specific details of experimental design or conditions of test.

Communication by Voice is Fast

One of the strongest generalizations emerging from our research is that:

1. Problems are solved significantly faster in communication modes that have a voice channel than in those that do not.

This finding is a consistent one that has come up in every one of the nine experiments in which this comparison was tested (Chapanis et al., 1972; Chapanis and Overbey, 1974; Ford, unpublished data; Hoecker, unpublished data; Krueger, unpublished data; Ochsman and Chapanis, 1974; Weeks and Chapanis, 1976; Weeks et al., 1974; Williams, unpublished data). Data from the first experiment in which this finding appeared are shown in Figure 7 (See also Figures 9 and 10). Even more interesting are the data in Figure 8 which compared 10 different communication modes. There is only one statistically significant effect for the data in Figure 8. The five modes on the left are significantly faster than the five on the right. The one thing that distinguishes the two groups is that the five modes on the left all have a voice channel. Those on the right do not.

The finding that people can talk faster than they can write or typewrite, and so can solve problems faster when they can talk, is not in itself particularly startling. However, these findings become more interesting when they are elaborated in the light of others below.

Face-to-Face Versus Voice Communication

A second strong generalization is that:

2. Both cooperative and conflictive problems are solved about equally fast in voice-only modes of communication as in face-to-face communication.

This finding came as a surprise to us initially but we have found it is no less than five different experiments (Chapanis et al., 1972; Hoecker, unpublished data; Krueger, unpublished data; Ochsman and Chapanis, 1974; and Weeks and Chapanis, 1976). The data in Figures 7 and 8 show that the voice-only modes of communication are a little slower than face-to-face communication in those two experiments. In neither case, however, is the difference statistically significant. In one very large experiment, the data came out the reverse, that is, voice only was faster than face-to-face communication (Figure 9). Once again, however, this particular difference is not statistically significant. Contrary to what one might expect, being able to see

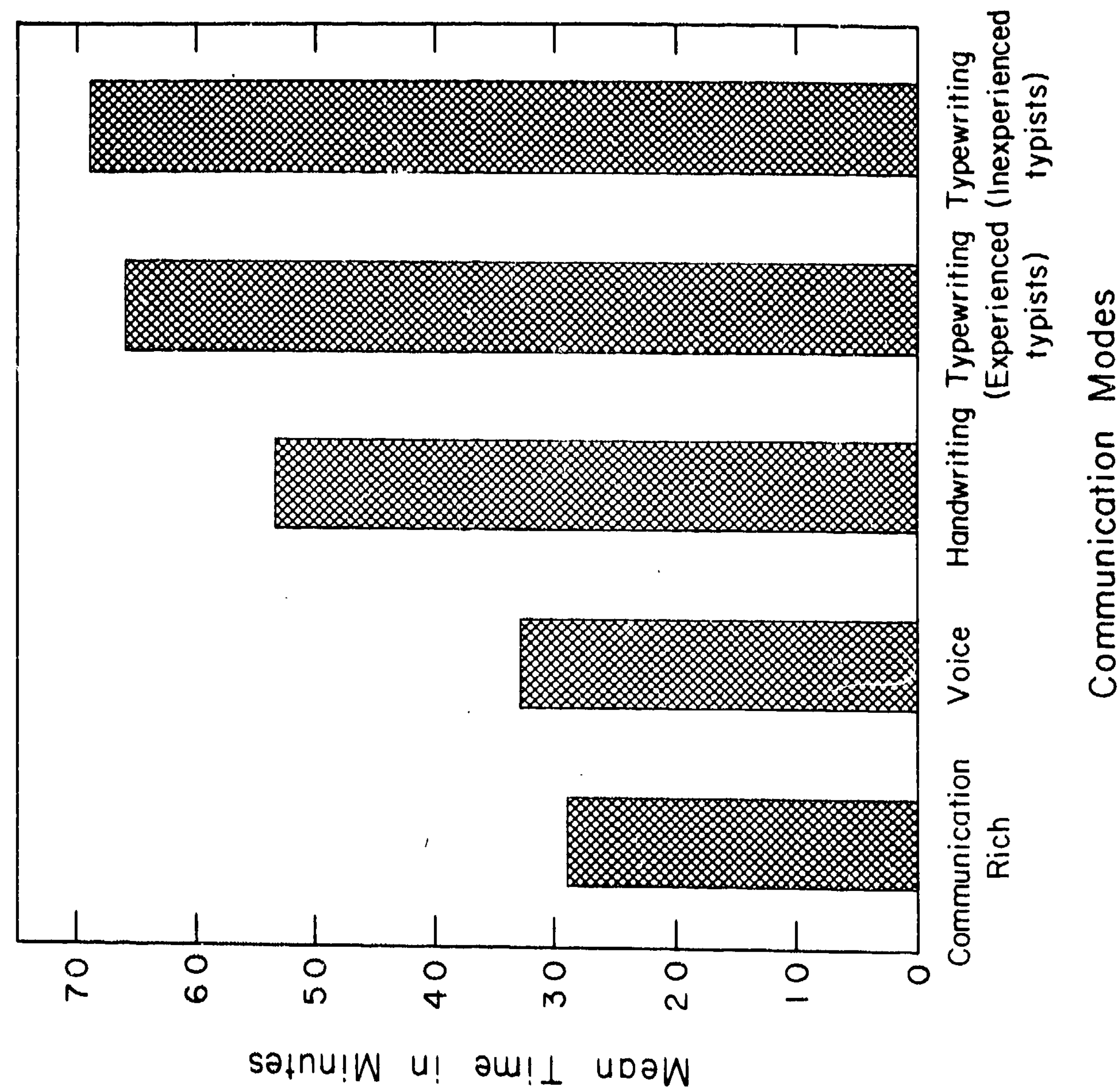


Fig. 7. Mean times to solve problems in four different communication modes. Each bar is an average for four two-man groups and for two different problems. (From Chapanis et al., 1972)

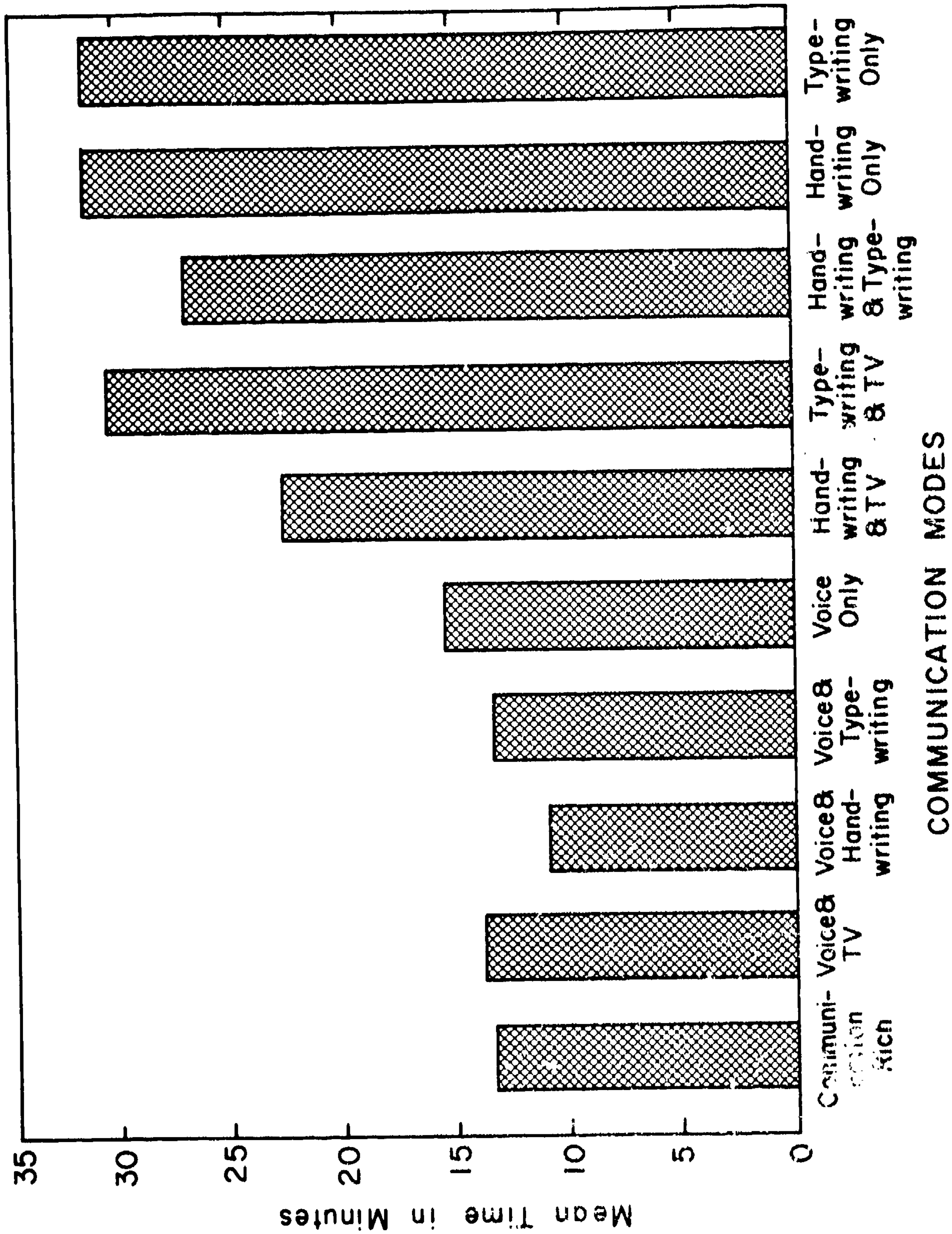


Fig. 8. Mean times to solve problems in ten different communication modes. Each bar is an average for six two-man groups and for three different problems. (From Ochsman and Chapanis, 1974)

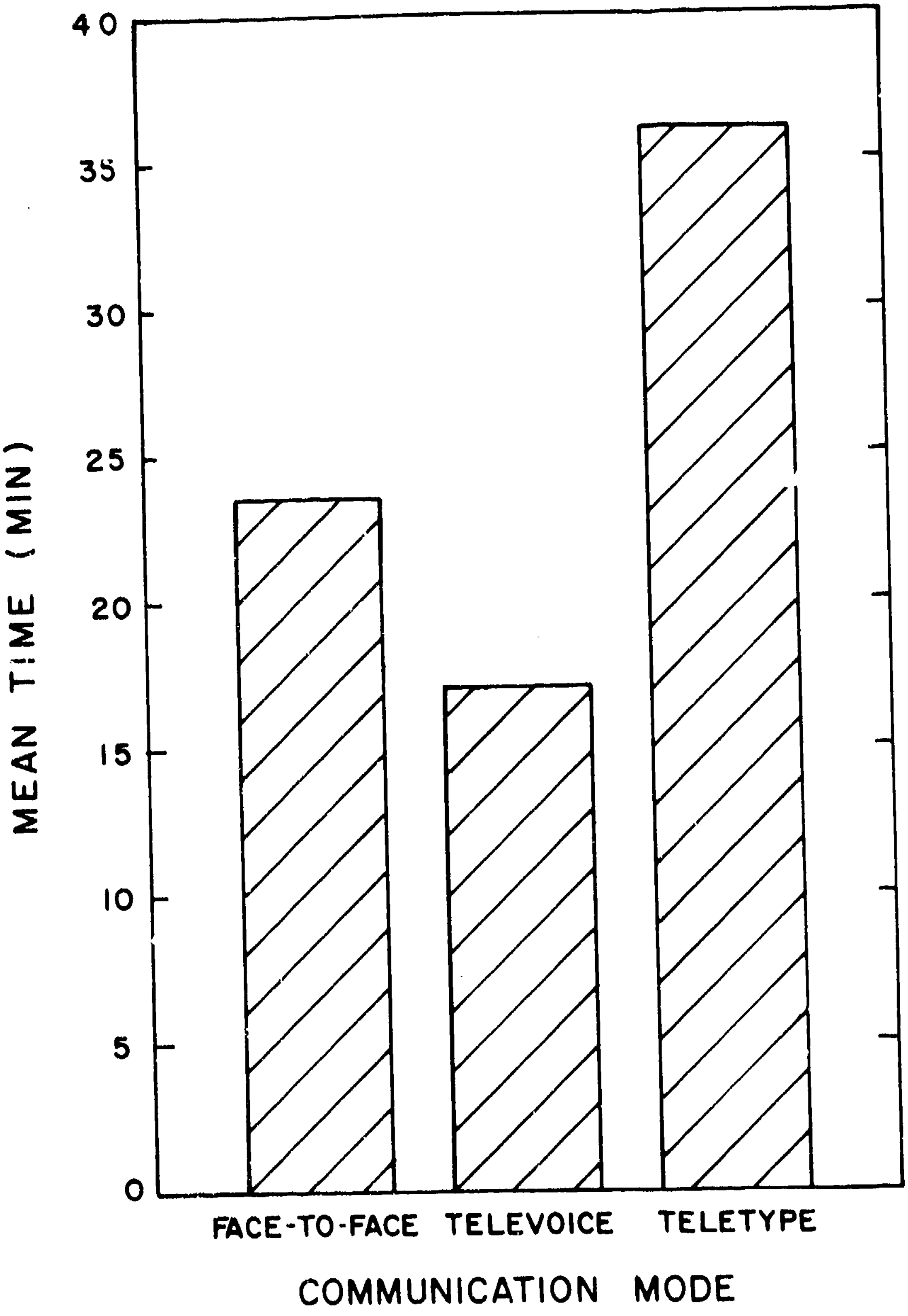


Fig. 9. Mean times to arrive at consensus agreements in three communication modes. Each bar is an average for three groups, each of which worked at a different task on each of three successive days. Each set of three groups was made up of a 2-person, a 3-person, and a 4-person group. (From Krueger, unpublished data)

the person(s) with whom one is communicating does not appear to be of any substantial advantage in solving the kinds of problems we have tested.

Skilled Versus Unskilled Typists

Of particular interest to man-computer interactions is that:

3. Typing skill does not appear to be a significant factor in the kind of communication with which we are concerned.

This finding appeared in our first experiment (Figure 7) in which we tested a group of high-school boys who had completed a one-year course in typing and another group without any formal typing education. As is apparent from Figure 7 the difference between the performance of the two groups was trivial. This finding was so unexpected that we tested it in another more elaborate experiment with a completely different set of subjects (Weeks et al., 1974). The essential findings of that experiment are shown in Figure 10. The skilled typists solved problems about nine minutes faster than did the unskilled typists in the typewriting mode. However, the skilled typists were very nearly that much faster than their unskilled counterparts in the communication-rich (face-to-face) mode as well. So, although the skilled typists seem to have been able to solve these problems somewhat faster, there is no evidence whatsoever in these data that typing skill per se gave the skilled typists any differential advantage.

The apparently counterintuitive finding that typing skill does not significantly aid interactive communication via typewriters can be explained by two additional considerations: (a) Activity sampling data on how subjects actually spent their time (Figures 10 and 11) show that only about one-third of the total problem-solving time is spent in sending, that is, in typing. This means that any potential advantage a subject might have due to typing skill would be operating only one-third of the time. (b) Typing skill is normally measured by the speed and accuracy with which typists copy prepared text. These communication situations, by contrast, require a great deal of planning and decision-making as subjects decide what to say and then compose their messages at the typewriter. Typing skill does not have very much to do with that kind of planning and decision-making.

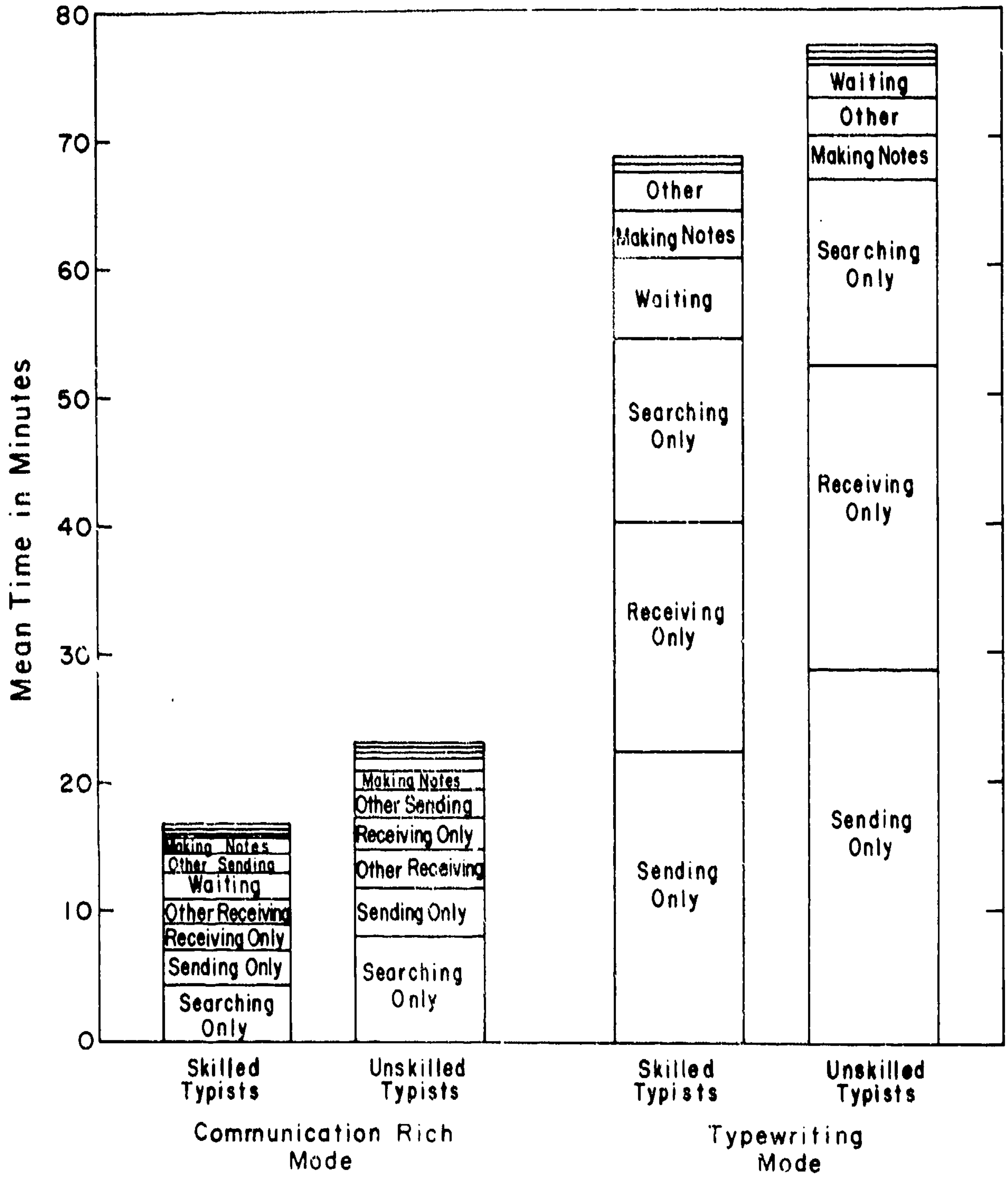


Fig. 10. Mean times to solve problems by pairs of skilled and unskilled typists each of which solved problems in two communication modes. Each bar is an average for four groups each of which solved a different problem on each of two different days. The segments of the bars show the average amounts of time subjects spent in each of nine activities. (From Weeks, Kelly and Chapanis, 1974)

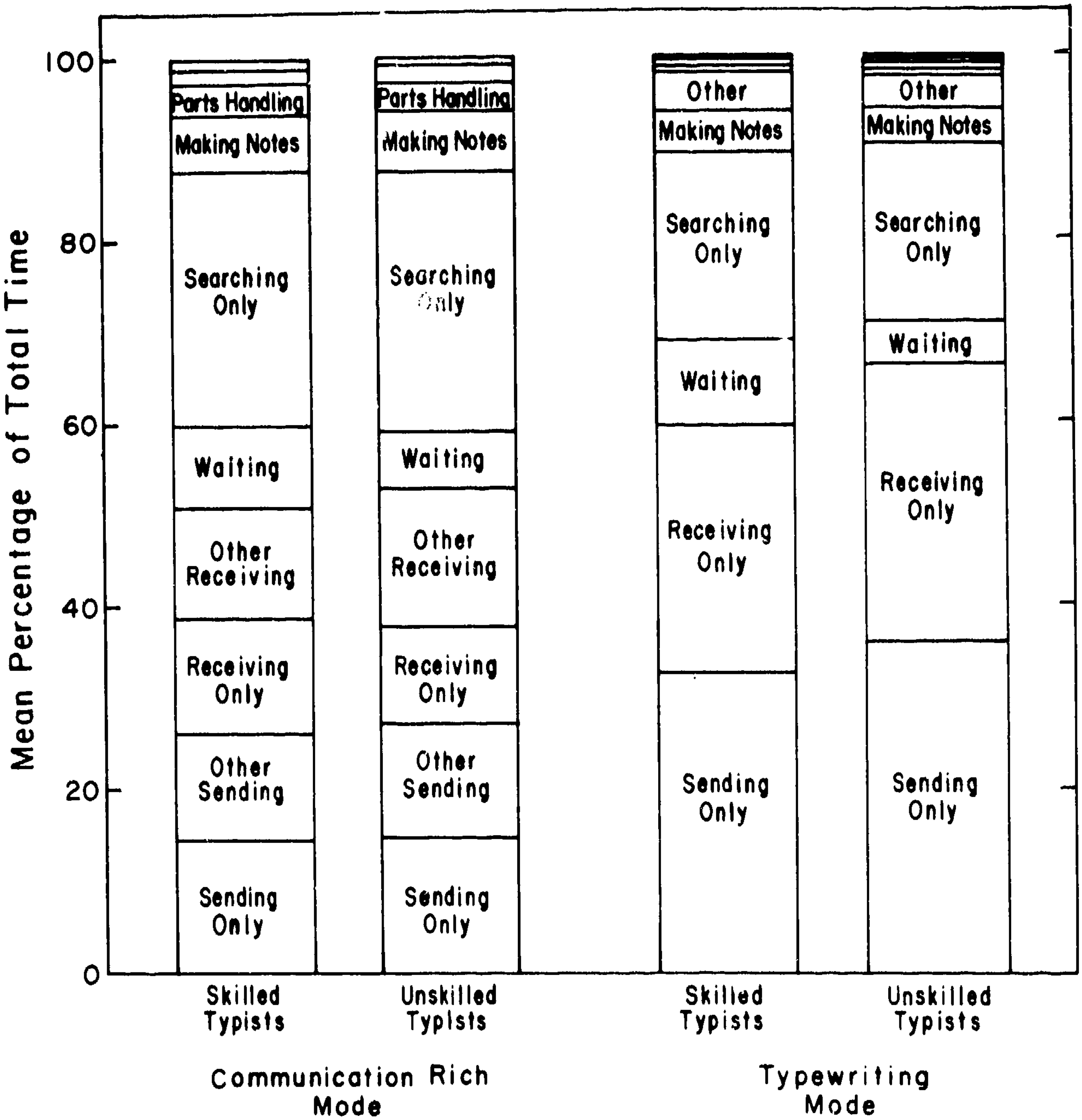


Fig. 11. The data of Figure 10 are here replotted as percentages of the total time. (From Weeks et al., 1974)

Verbal Output

Another strong finding from a number of our experiments is that:

4. Modes of communication that have a voice channel are much wordier than those that do not have a voice channel.

This generalization holds no matter how one measures wordiness, or verbal output. Figure 12 shows the number of words communicated in the four modes tested in our first experiment. These data match those in the same experiment for which Figure 7 gives times to solution. Considering that problems are solved about twice as fast in the voice modes as in the hard-copy (handwriting and typewriting) modes, the data in Figure 12 become all the more impressive (See also Figure 14). Figure 13 shows communication rates from the same experiment. These were computed by dividing the number of words used by each subject by the actual amount of time he spent communicating. If computers will ever be able to accept spoken words, communication rates will be much greater than has been the case with typewritten inputs.

Face-to-Face Communication Versus Communication by Voice Only

A small, but consistent finding that has turned up repeatedly in our work is that:

5. Face-to-face communication is wordier than communication by voice only.

Data for this generalization appear in Figures 12 and 13. The differences between the communication-rich and voice only data in these two figures are not statistically significant and one might be inclined, therefore, to attribute them to chance variations. However, the finding has turned up in all four experiments in which there has been a comparison of the verbal output in face-to-face and voice only modes. Figure 14, for example, shows another and much greater difference than we found in our earlier work. Being able to gesture and use body movements to convey information actually seems to increase the number of words communicators use.

Verbal Output Independent of Mode of Communication

An interesting finding that has turned up in our experiments bears on the stability of the verbal output in the several modes. It is:

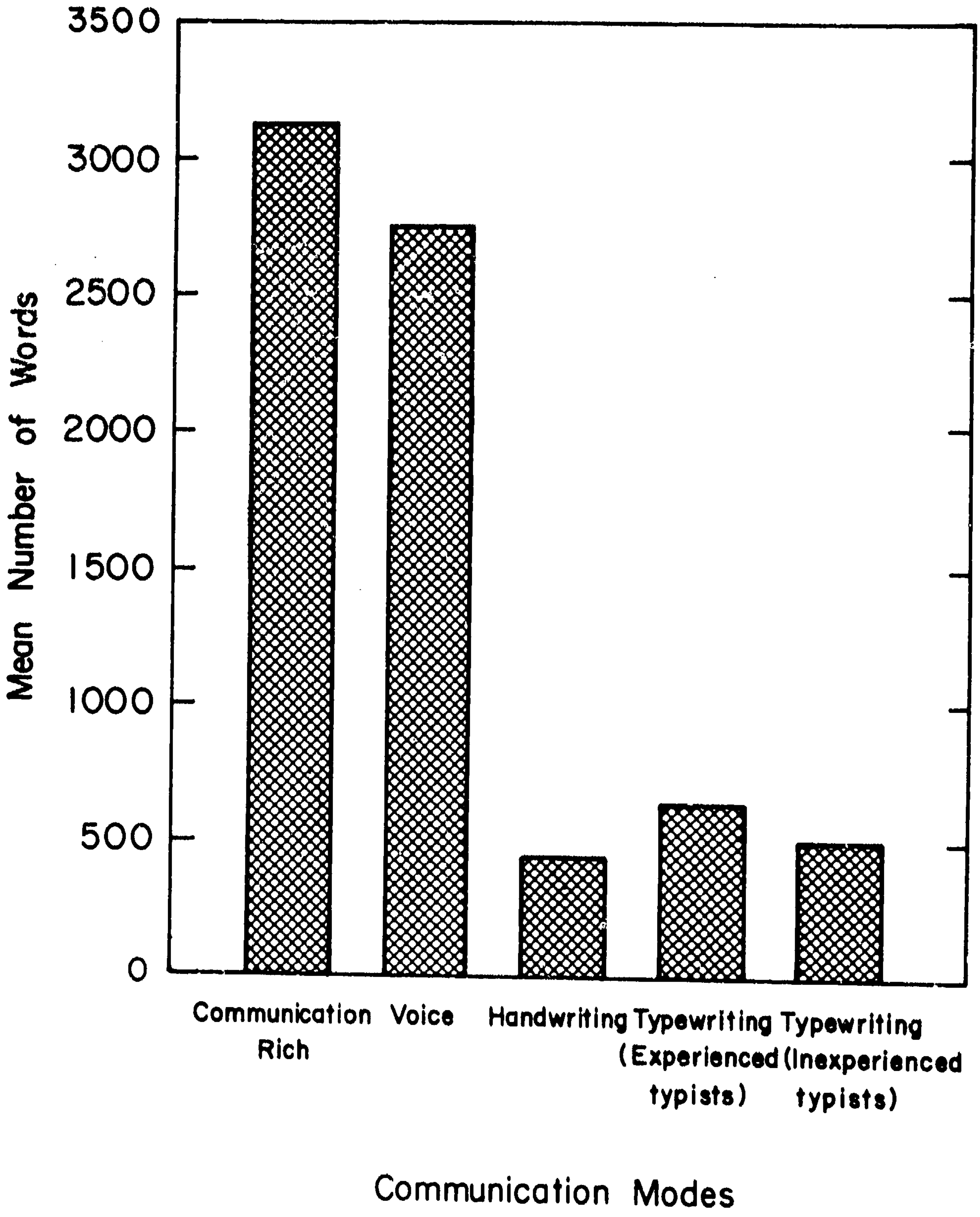


Fig. 12. Mean number of words used in the solution of problems in each of four communication modes. These data and those in Figure 7 are from the same experiment. (From Chapanis et al., 1972)

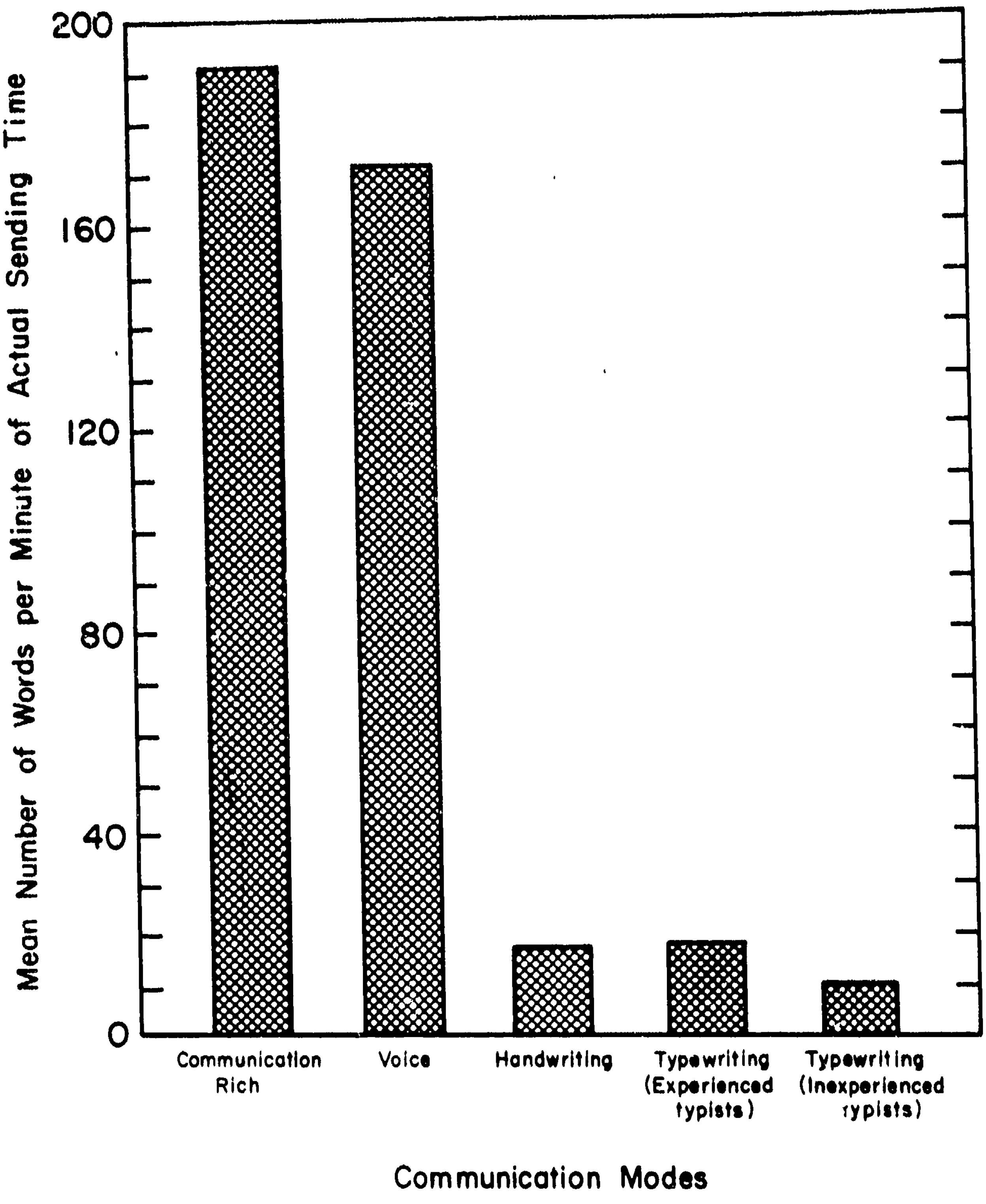


Fig. 13. Communication rates in the solution of problems in each of four communication modes. These data and those in Figures 7 and 12 are from the same experiment. (From Chapanis et al., 1972)

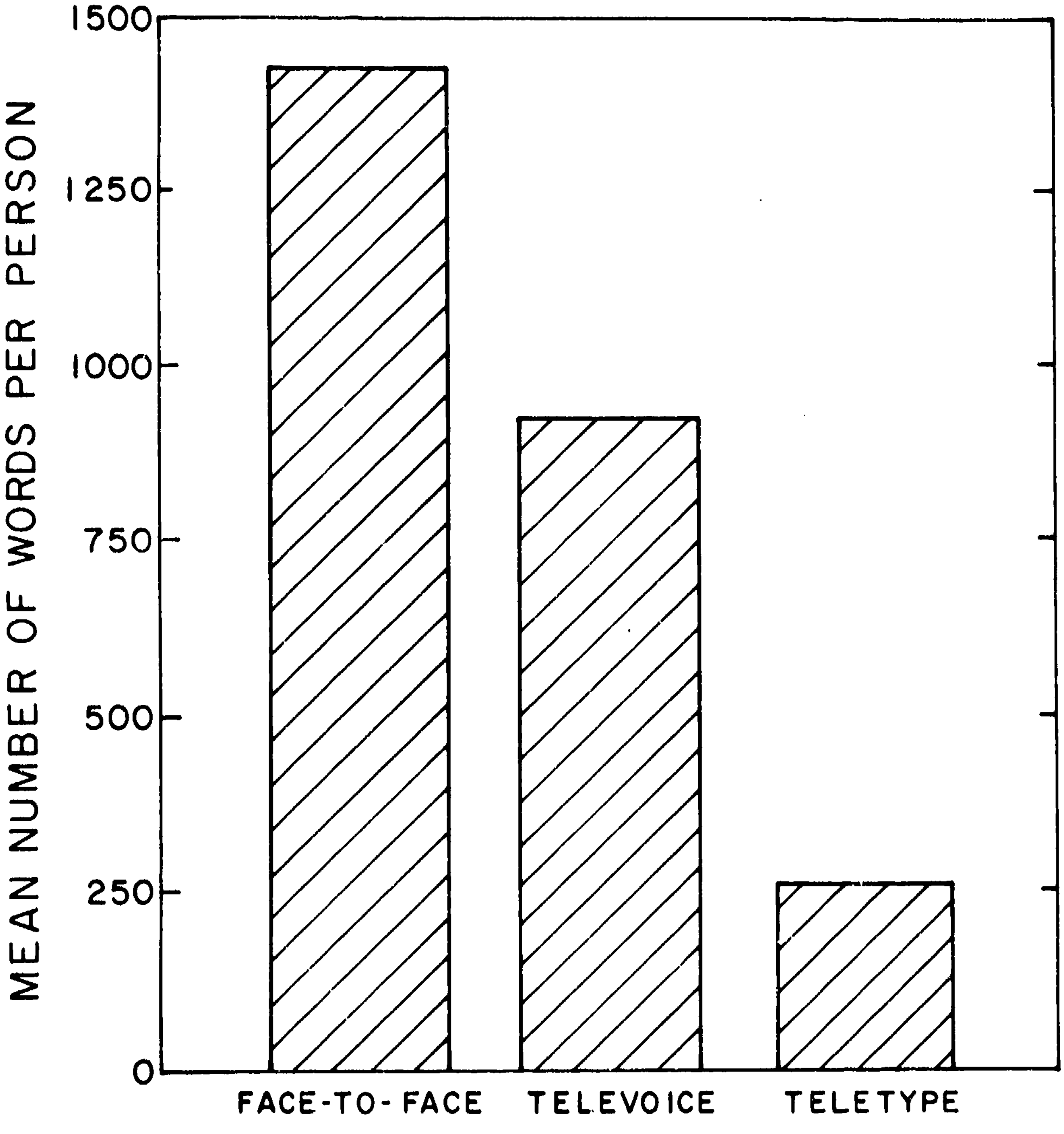


Fig. 14. Average number of words used in arriving at consensus agreements in three communication modes. These data and those in Figure 9 are from the same experiment. (From Krueger, unpublished data)

6. The number of words used by a communicator is a function of the communication channel and that number is not influenced by the channel available to his partner.

Data supporting this statement are shown in Figure 15. The left-most pair of bars gives data for a situation in which both the seeker and source had a voice channel. The second pair of bars is for a condition in which the seeker had a voice channel, but the source could communicate only by typewriter. The third pair of bars is for the reverse situation: the seeker could communicate only by typewriter, while the source had a voice channel. The right-most pair of bars is for the condition in which both persons could communicate only by typewriter.

When both communicators had a voice channel (left-most pair of bars), the seeker used more words than did the source (See the filled bar). When the seeker had a voice channel and the source a typewriter channel (third pair of bars), the average number of words used by the seeker was almost identical to the number used by seekers in the voice-voice condition. Similarly, the numbers of words used by sources was almost identical when they communicated by voice, irrespective of whether the seeker had a voice channel or a typewriter channel (compare the open bars in the first and second pairs). Similar findings apply to the data for the tyepwriter channels. To sum up, the number of words used by a communicator is a function of the channel available to him and is not influenced by the channel available to his partner.

Interrupt Capability

In one experiment we tested the effects of giving communicators the freedom to interrupt their partners. The findings of that study support the conclusion that:

7. Giving communicators the freedom to interrupt has no effect on problem solution time or on the number of words used. Words are, however, "packaged" differently. When communicators have the freedom to interrupt, they use more messages and messages are shorter. When communicators do not have the freedom to interrupt, they use fewer messages and messages are longer.

Date supporting these conclusions are given in Figure 16 and 17. In the free interchange conditions, a communicator could interrupt his partner at any time and take control of a voice channel, or a typewriter channel. In the restricted interchange condition, a communicator had to wait until his partner had finished talking, or typing, and had released the channel to him. The data in the two figures are

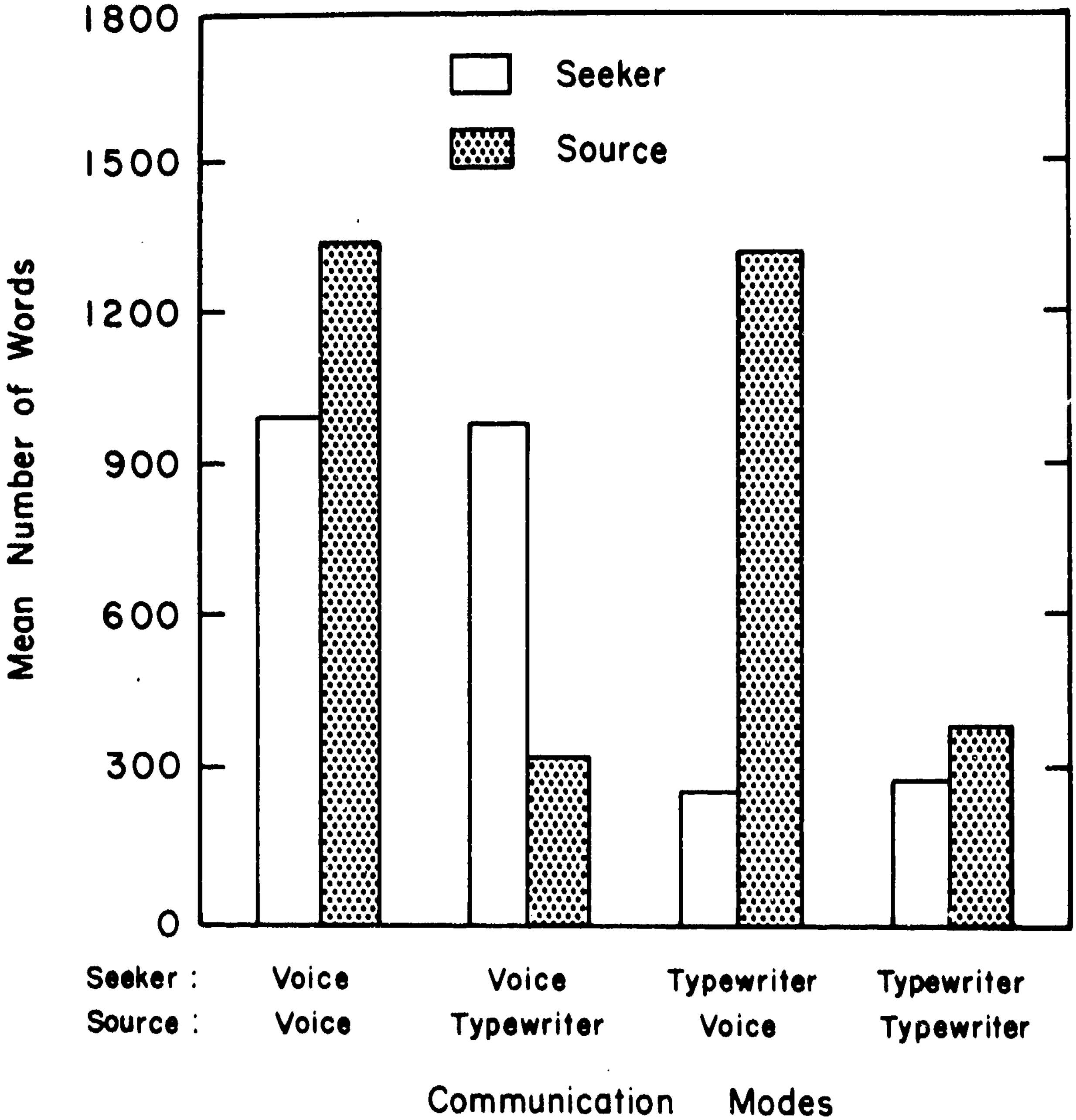


Fig. 15. Mean number of words used by sources and seekers when two channels of communication were tested in all combinations. Each bar is the average for eight subjects, two each of whom solved one of four different problems on one of four different days. (From Chapanis and Overbey, 1974)

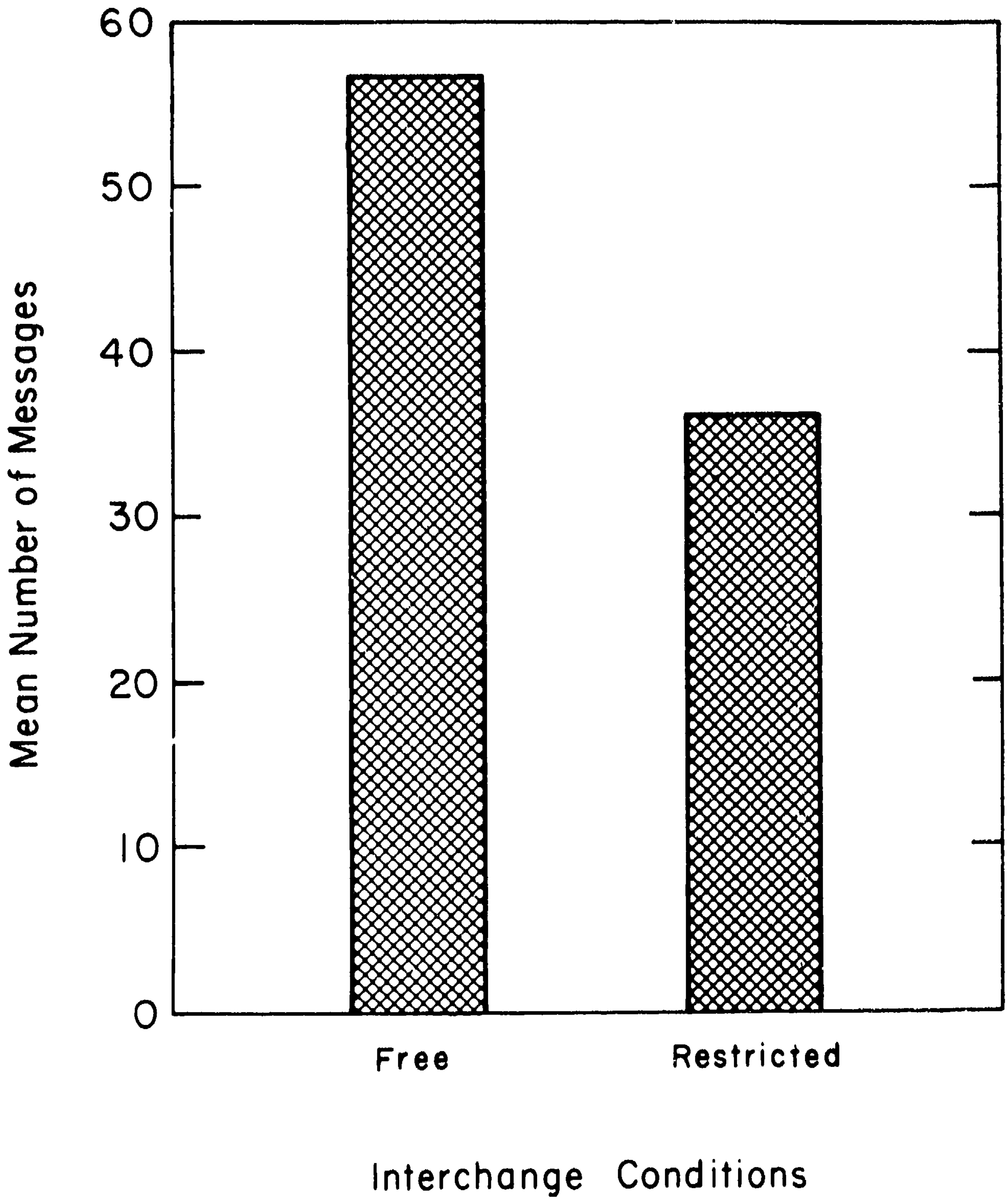


Fig. 16. Mean numbers of messages exchanged under conditions of free and restricted interchange. Each bar is an average of 64 observations. Eight two-person teams each solved four different problems on four different days using each of the channel combinations illustrated in Figure 15. (Chapanis and Overbey, 1974)

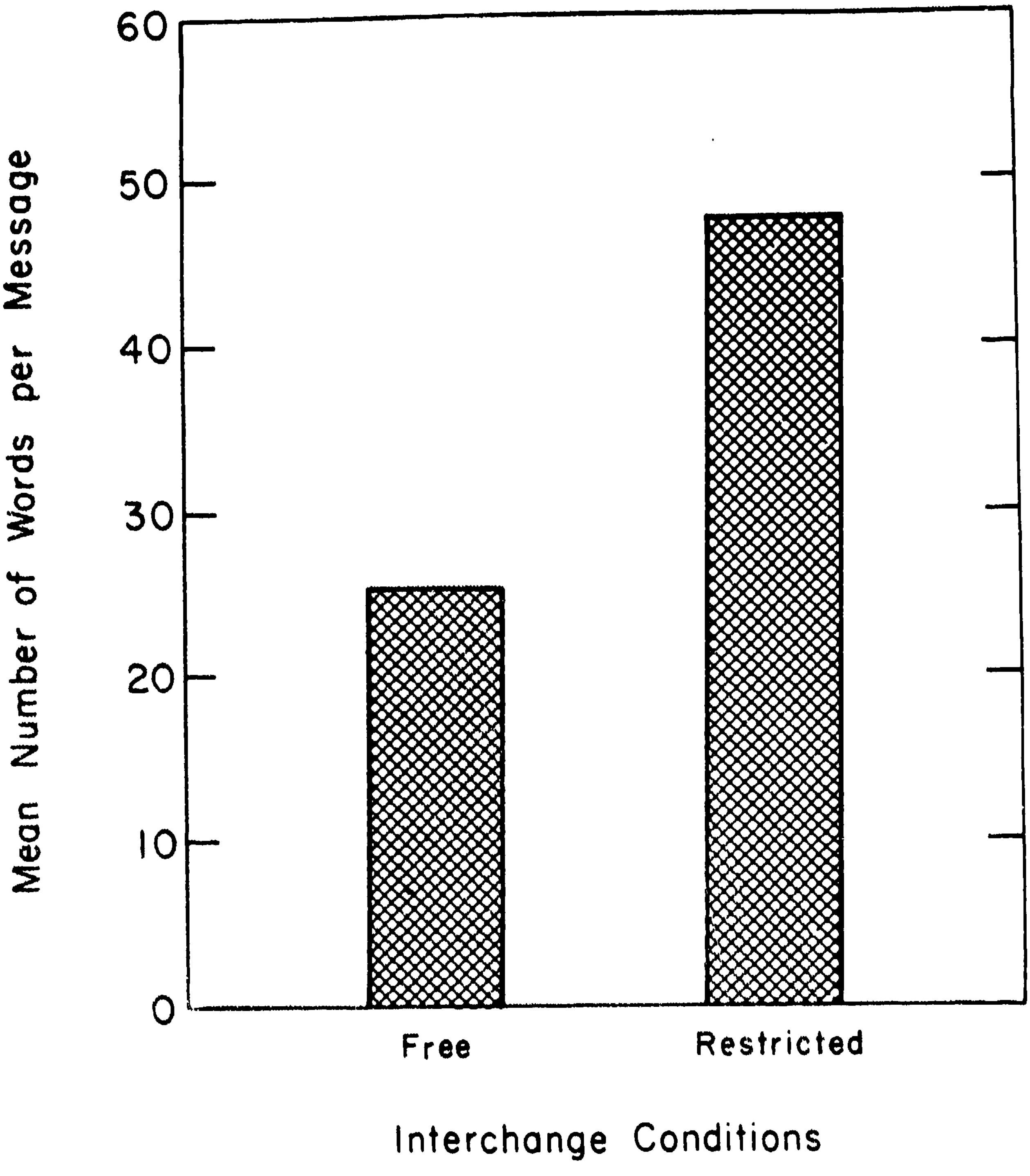


Fig. 17. Mean message lengths for the same data as are shown in Figure 16. (From Chapanis and Overbey, 1974)

almost mirror images of one another. When the two sets of data are multiplied together, they yield essentially equal numbers of words.

Control over Communication Channels

In one experiment we gave subjects two buttons. When a subject pressed one button, he relinquished control of the communication system to his partner. When a subject pushed the other button, he took control away from his partner, even if the partner was in the process of communicating. The findings of this experiment suggest that:

8. Communicators are much more likely to take control of a communication system (that is, to interrupt) if the system has a voice channel. Subjects voluntarily relinquish control of a system about as often as they take control if the system has only hard-copy channels of communication.

Data supporting this finding appear in Figure 18. Note that in every one of the five pairs of bars on the left, subjects took control of the communication system much more often than they relinquished control. All five of those communication systems have a voice channel. By contrast, the five pairs of bars on the right are about equally high. Those five pairs of bars are for communication modes that do not have a voice channel.

Time Spent in Various Activities

In seven of our experiments (Chapanis et al., 1972; Chapanis and Overbey, 1974; Kelly, 1976; Ochsman and Chapanis, 1974; Parrish, 1974; Weeks and Chapanis, 1976; Weeks et al., 1974) we used activity sampling procedures to record what subjects were actually doing in the problem solving sessions. The findings of those experiments lead us to conclude that:

9. In tasks requiring the exchange of factual information to solve problems, only about half a communicator's time is spent in actual communication, that is, in sending or receiving information. The rest of the time is spent in doing other things, for example, making notes, handling parts, or searching for information. When the task involves the exchange of opinions and argumentation, as much as 75 percent of a person's time may be spent communicating. However, at least 25 percent of a communicator's time is still spent in other activities, for example, making notes and searching for information.

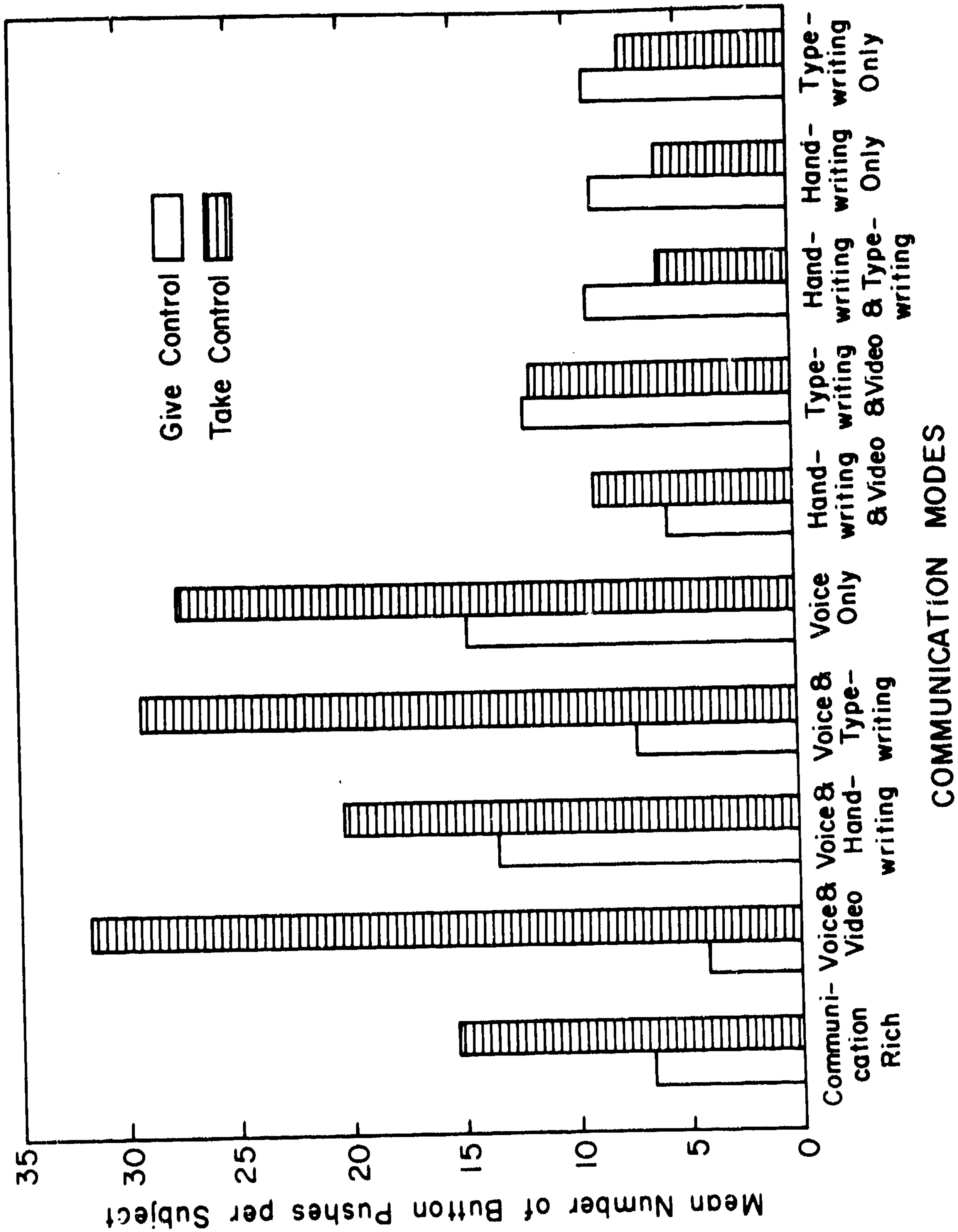


Fig. 18. The mean number of times subjects gave and took control of communication channels. These data and those in Figure 8 are from the same experiment. Each bar here is based on 12 observations. (From Ochsman and Chapanis, 1974)

In our first experiment, we recorded behavior in each of 15 different categories. The data are shown in Figures 19 and 20. Perhaps the most impressive thing about both figures is that in four of the five bars the behavior consuming the largest single amount (or percentage) of time was something other than sending (that is, communicating). Only in the case of the inexperienced typists did sending take up the greatest amount, or percentage, of time. In this experiment, one problem solving task required subjects to assemble a trash can toter, the other to find a particular address on a street map of Washington, D.C. from telephone directory information. These are tasks requiring the use of pieces of equipment, or pieces of paper.

Our conflictive problems, for example, the national issue-ranking problem, are quite different in that there is no supplementary material required to arrive at agreement. Pieces of paper are typically used, however, to jot down notes. Mainly the communicators are required to voice their opinions and to argue the merits of their respective positions. Under these circumstances, the proportion of time spent communicating increases and it has gone as high as 75 percent. Even so, 25 percent or more of a typical communicator's time is spent in other activities, for example, making notes, searching for information, or waiting. Data to support these findings are not given here, but may be found in Weeks and Chapanis (1976).

Level of Sophistication of the Communicators

We have completed two experiments in which the level of sophistication of the communicators was systematically varied. At the time of this writing, the data from one of those experiments have still not been completely analyzed. Hence, the following two generalizations are based on the results of only one experiment (Parrish, 1974). Those findings show that:

> 10. The greater the level of sophistication of the communicators, the more quickly they are able to solve problems.

Data supporting this generalization appear in Figure 21. The teams here were made up of various combinations of high school and college students who served as seekers (SK) and sources (SO). College teams arrived at solutions fastest; high school teams slowest. When teams were mixed, it was better to have a college student as the source rather than as the seeker.

These findings can be explained by the greater facility college students have in using language. In our problems, the source was given the bulk of the library-like, or stored information. It was he who gave directions or instructions to the seeker about how to complete

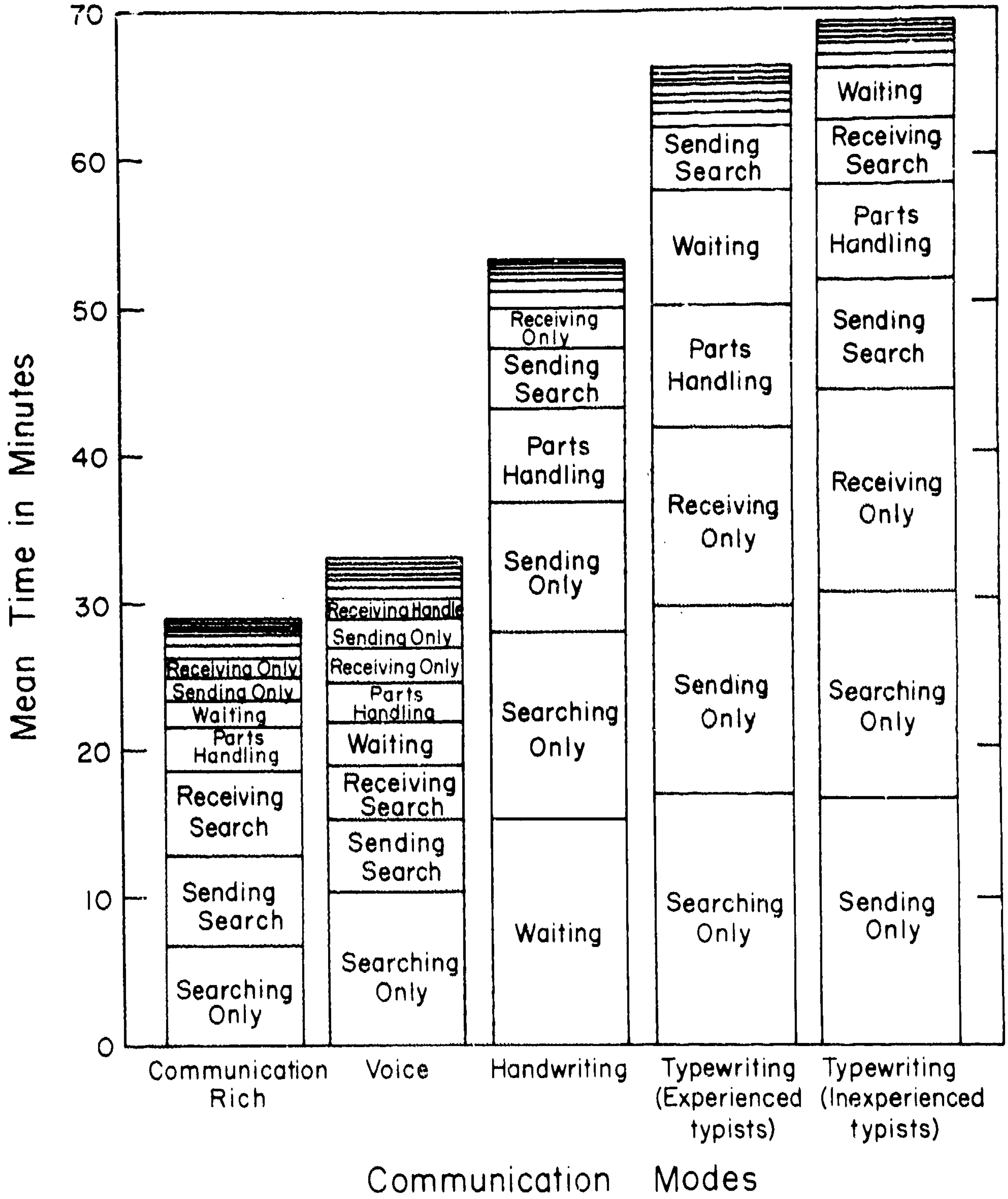


Fig. 19. The data of Figure 7 are segmented here to show the amounts of time subjects spent in each of 15 different activities during problem-solving sessions. (From Chapanis et al., 1972)

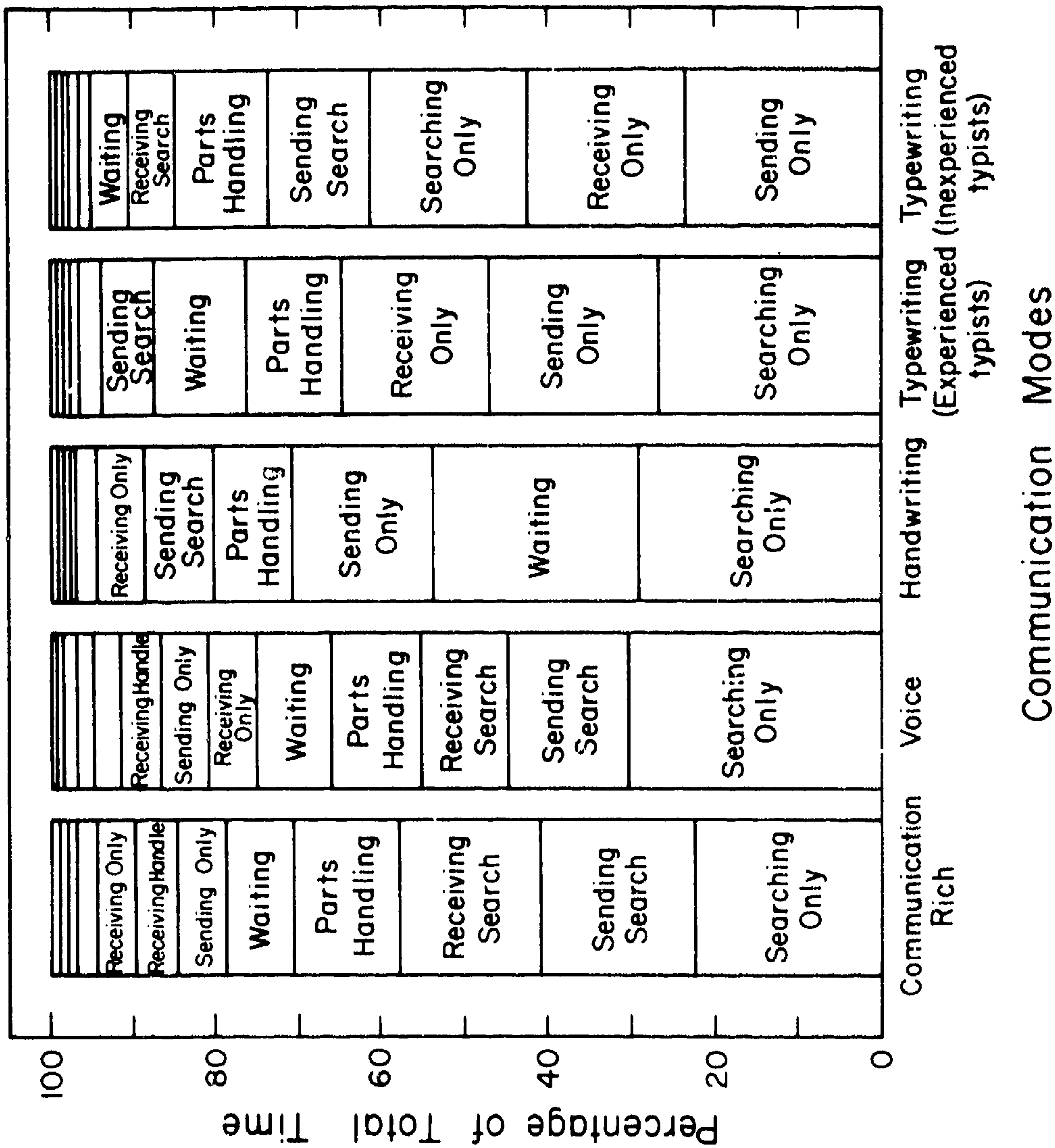


Fig. 20. The data of Figure 19 are replotted here as percentages. (From Chapanis et al., 1972)

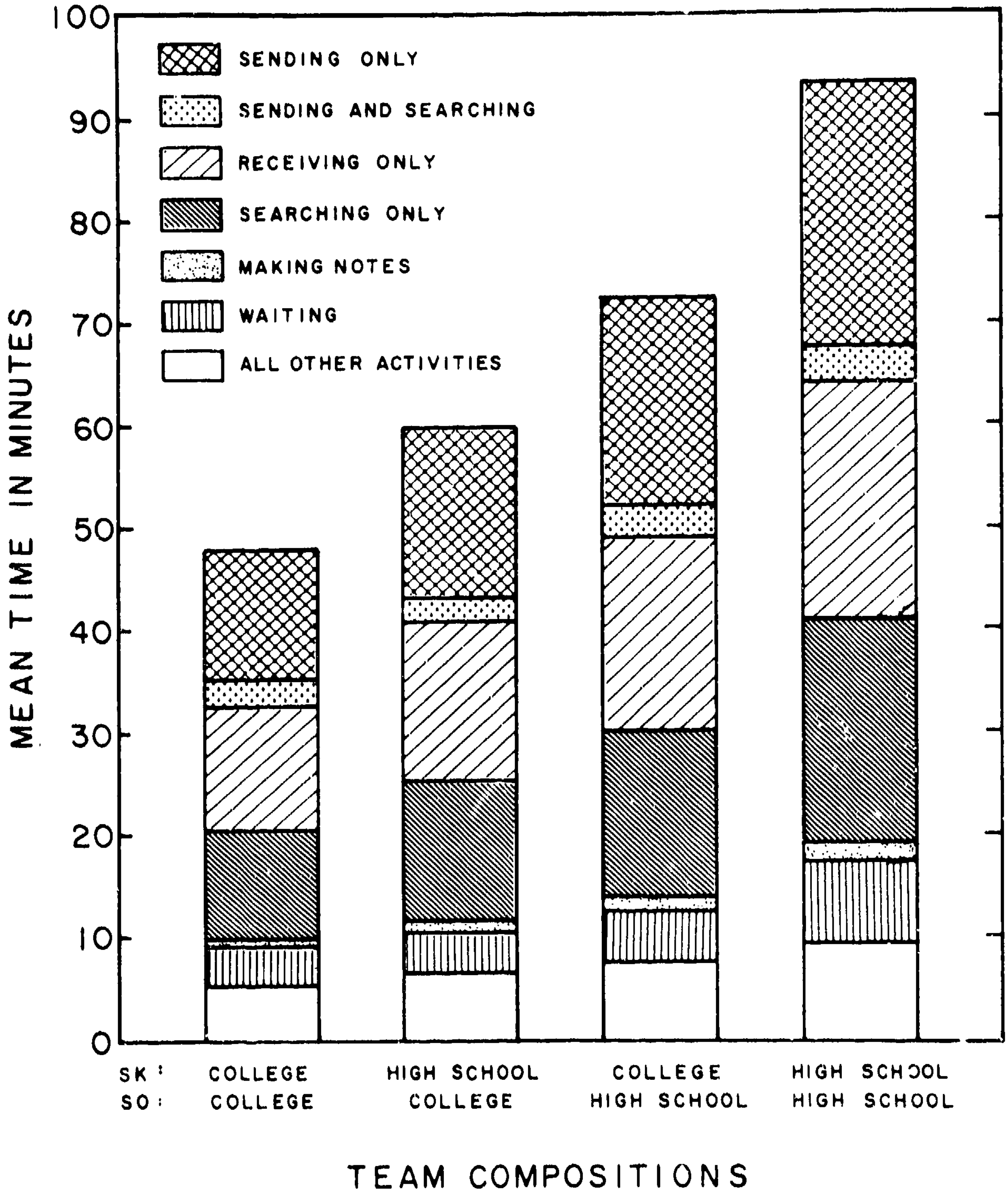


Fig. 21. Times to solve problems by combinations of high school and college students. Segments of the bars show the amounts of time spent in each of seven different activities. (From Parrish, 1974)

the problem at hand. This accounts for the faster performance of the mixed teams in which a college student served as source.

Even more interesting, perhaps, is the finding that:

11. In these communication tasks, college students and high school students do about the same kinds of things, and in the same proportions. However, college students do everything faster.

Data in support of this conclusion are given in Figure 22. The four bars in Figure 22 are so nearly alike that they seem to be traced from the same pattern!

Impersonality of the Communication Modes

It has been claimed that teletype or computer conferencing is more egalitarian and impersonal than face-to-face communication. We have some evidence for that claim from one of our experiments. The findings of that experiment suggest that:

12. Communicators in teletype modes of communication are much more likely to share equally in the exchange of information than are communicators in face-to-face or voice only modes of communication.

Data for that generalization are given in Figure 23. The mean relative variability (MRV) is based on a statistical measure called the coefficient of variation, $MRV = CV = 100 \frac{\sigma}{M}$. In essence, this measure is an expression of the amount of variability (σ) among the various communicators in the numbers of messages they exchanged, when that variability has been compensated for the average number of messages (M). Larger numbers indicate greater disparity in the numbers of messages produced by the several communicators. Smaller numbers indicate that the several communicators shared more nearly equally in the production of messages.

The figure shows that communicators in the teletype mode produced much more nearly equal numbers of messages than did communicators in either of the voice modes. Conversely, in the voice modes, some communicators tended to produce a disproportionately large number of messages, while others tended to be less communicative than would be expected. These data, incidentally, are averages for 2-person, 3-person, and 4-person conferences. Since there was no significant interaction between size of group and communication mode, the data in Figure 23 hold for all three sizes of group.

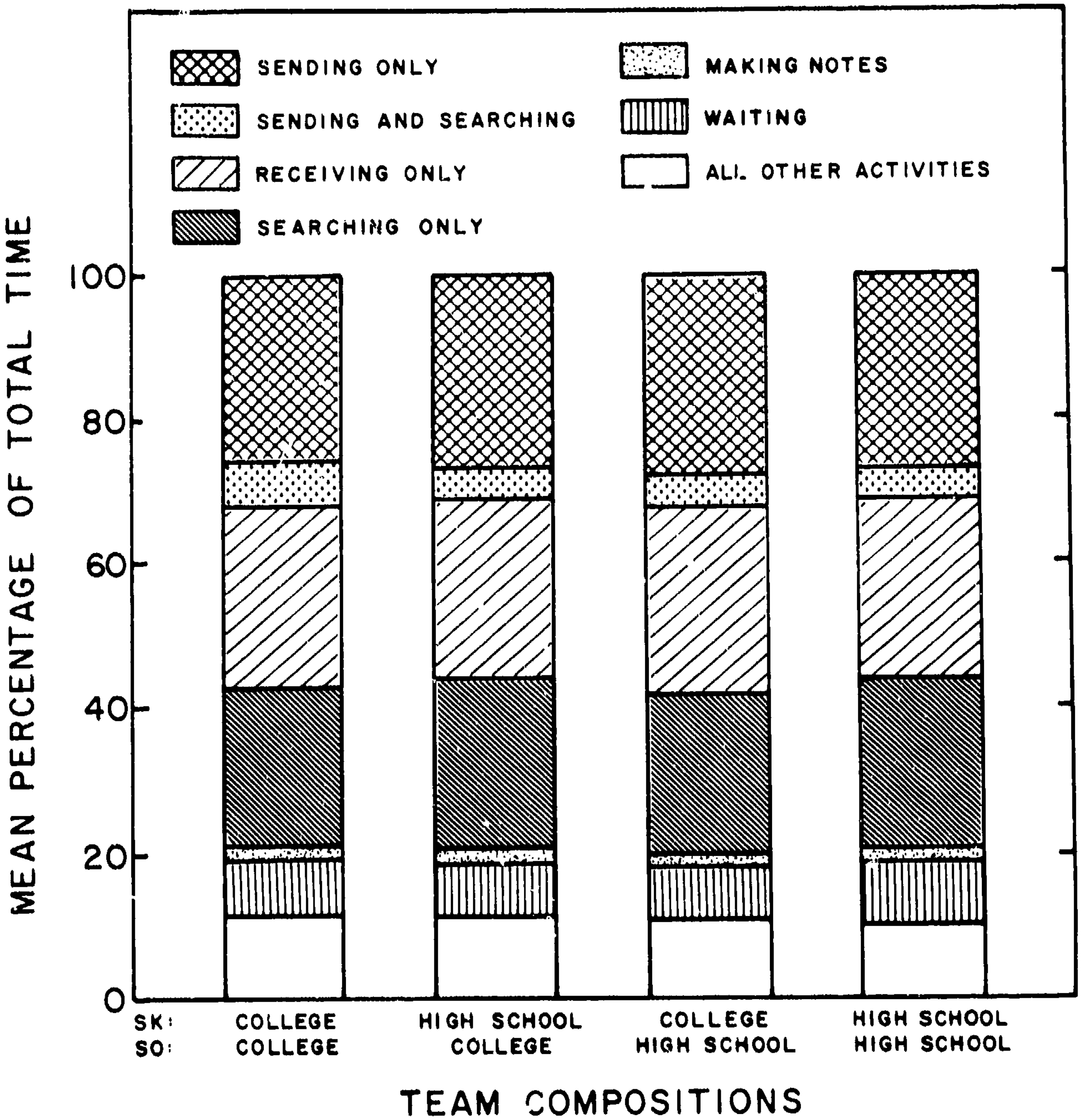


Fig. 22. The data of Figure 21 are here represented as percentages. (From Parrish, 1974)

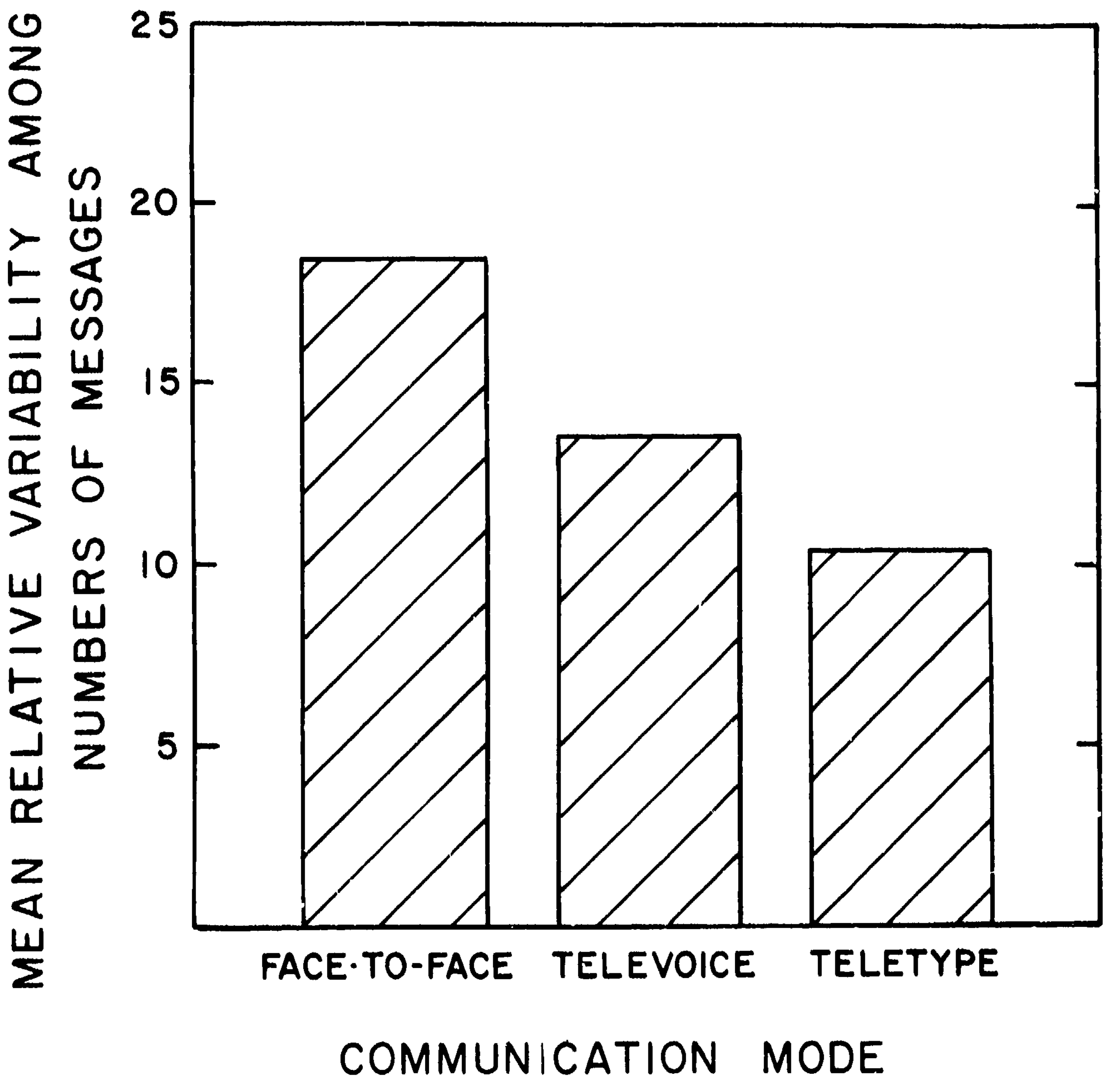


Fig. 23. Mean relative variabilities among the numbers of messages produced by communicators in three modes. Each bar is the average of 54 data points. Data are averaged for three sizes of conference group, each of which arrived at solutions to three different problems on each of three successive days. (From Krueger, unpublished data)

Linguistic Categories in the Several Modes of Communication

The striking differences in verbal output among the several modes of communication (Refer to Figures 12, 13, 14, and 15, for example) have led us to examine more closely the kind of language and words that are used in the various modes of communication. Here I shall only give two generalizations that seem to emerge from our studies.

> 13. We have not been able to find any outstanding differences in the various kinds of words people use in the several modes of communication.

Figure 24 shows the average numbers of words in each of six linguistic categories based on a modification of the Fries (1952) classification system. These data and those in Figure 12 are from the same experiment. About the only thing one can conclude from Figure 24 is that the differences among the several modes revealed by total word counts appear to hold for words in every linguistic category. Indeed, when the data of Figure 24 are converted to percentages (Figure 25), the prevailing impression one gets is that there are no striking differences among the various kinds of words in the several modes of communication. That impression is confirmed by appropriate statistical tests of the data.

The foregoing notwithstanding, additional studies lead us to conclude that:

> 14. Oral communication is highly redundant and most communication can be carried on effectively with a small, carefully selected set of words.

Because of the nature of natural language communications, redundancy cannot be measured in the ordinary mechanical ways that have been developed from Shannon's theory of information. However, using some plausible assumptions, we have been able to estimate that oral modes of communication use about 12 to 14 times as many words as are necessary and about 4 times as many different words as are necessary (Chapanis, Parrish, Ochsman, and Weeks, in press).

One heartening thing for purposes of man-computer communication is that people can carry out our communication tasks by using no more than 300 words (Kelly, 1976) and can do the tasks just about as effectively as they can with no vocabulary restrictions. Let me assert at once, however, that this is a specially selected subset of 300 words. Not any set of 300 would do. Additional studies (Ford, unpublished data; Michaelis and Chapanis, in progress) are looking at

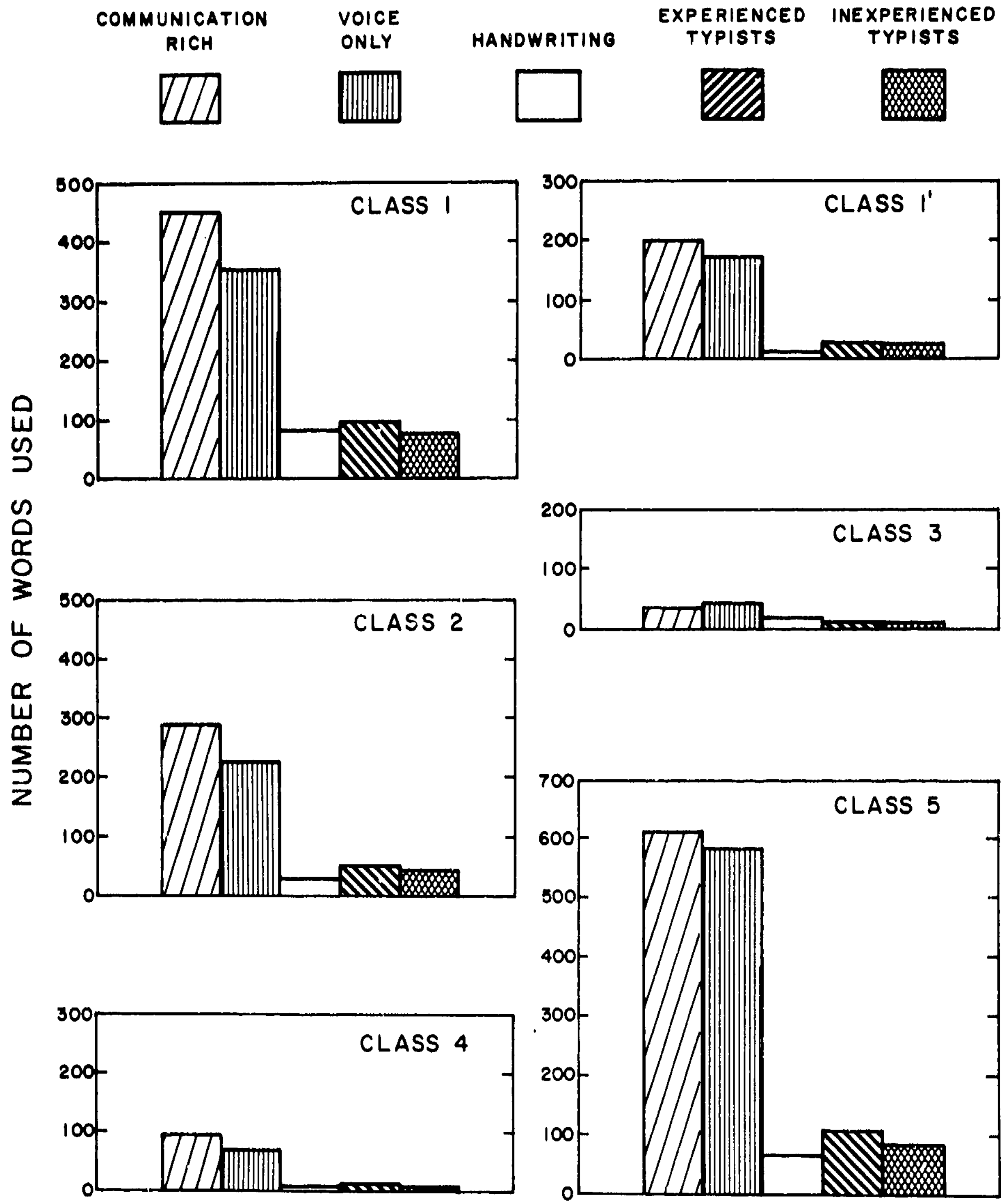


Fig. 24. Average numbers of words in each of six linguistic categories by subjects in each of four modes of communication. (From Stoll et al., 1976)

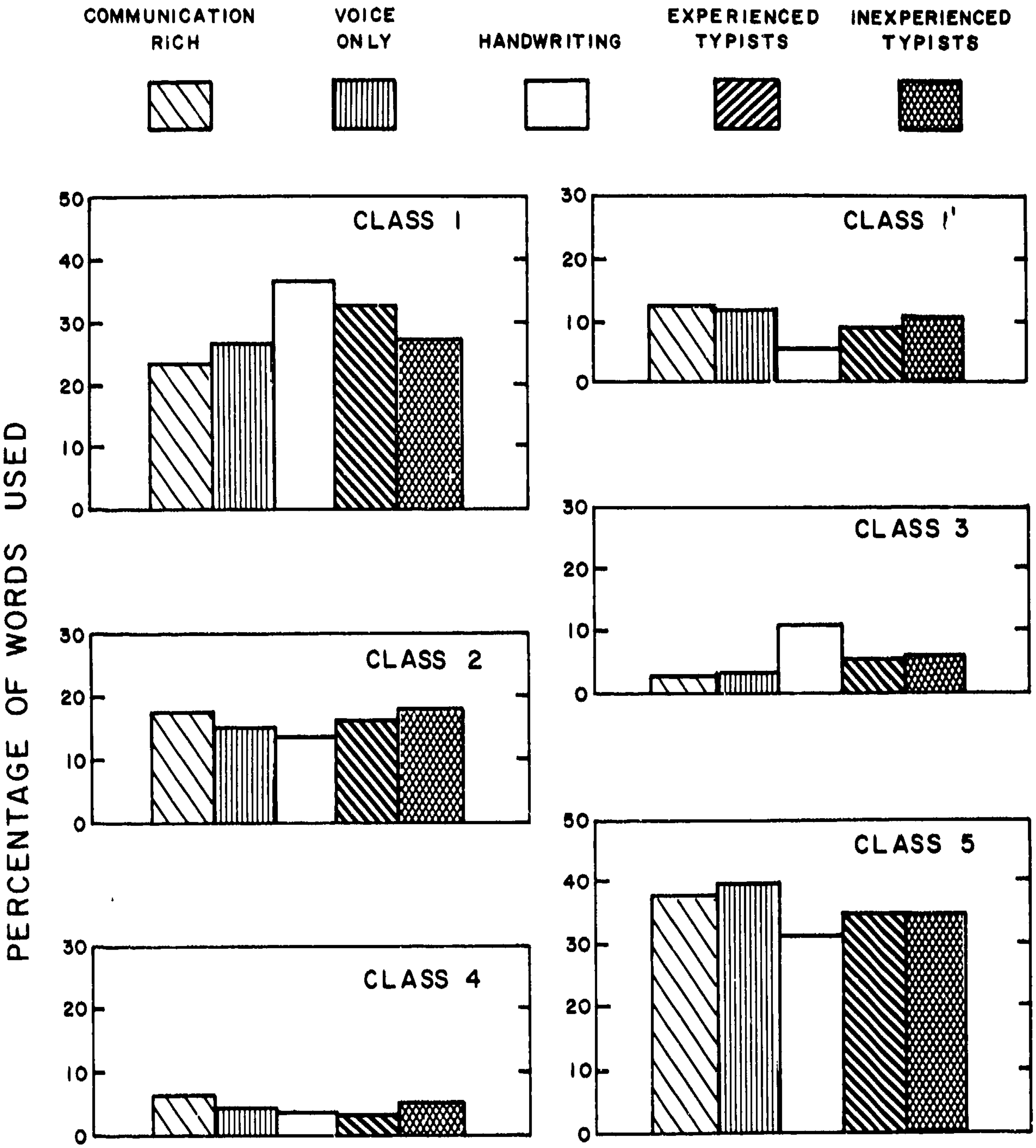


Fig. 25. The data in Figure 24 have been here converted to percentages. (From Stoll et al., 1976)

still more restricted sets of language and their effects on communication. It is still too early to say what these experiments will show.

The Chaos of Ordinary Communication

In the preceding sections of this paper, I have spoken rather glibly about numbers of words and numbers of messages as though it were no trouble at all to count such linguistic units. Let me disabuse you of that impression with my next generalization and with some illustrations:

> 15. Natural human communication is extremely unruly and often seems to follow few grammatical, syntactic, or semantic rules.

Most psycholinguistic experiments are done with what I have called "immaculate prose." Words are formed into perfect sentences, with nouns, verbs, adverbs, and other parts of speech all in their correct order. Natural human communication is not at all like that. Most people know that ordinary communication tends to be somewhat disorganized, but few of us really appreciate how disorganized it can be. Many of our protocols contain not a single grammatically correct sentence. Moreover, we find every rule of spelling, abbreviation, punctuation, and format repeatedly violated.

Figure 26 shows the start of some interchanges between two persons who communicated via teletypewriter to solve a faculty selection problem. Figure 27 shows the start of the interchanges between two persons who communicated by voice to solve the problem illustrated in Figures 5 and 6. Figures 28 and 29 are segments of two protocols from persons who communicated by telepen to solve the wiring problem illustrated in Figures 3 and 4. The protocols in Figures 26, 27 and 28 are typical of what one can get in these various modes. Figure 29 is an extreme example to show how bad protocols can get.

Perhaps the most impressive thing about these samples of protocol is their extreme unruliness. It is even difficult to know what to count as a word, a sentence, or a message. I think we have made a good start on this problem and a paper in press (Chapanis, Parrish, Ochsman, and Weeks) describes some empirical rules we have developed for dealing with some of these natural language protocols. That same study leads us to conclude that:

SK: Need information . Use form of a list for clarity. Present info on all candidates in the area of research each has done..

end my typing go.

SO: A: The Eskimo as a Minority Worker in Alaska
Sikudaruty (Ignore) Solidarity Fornation Between Blue and White Collar Workers in Adverse

SK: wait/////////////   ignore info about topics ... Can you give data of 1. quantity of research done as manifested in # of publications etc. If not, move on to (past experience in teaching) present in same fashion..... Please give SYNOPSIS of material for efficiency/////++++++

SO: A: 3 publications
B:none
C: 3 pub.
D: 4 publ.
E. Dissertation research: The Existance of a Pecking Order in Penal Cloonies

SK: Information on AWARDS RECEIVED BY ANY OF CANDIDATES OR HINT OF QUALITY OF RESEARCH ? Then move on to teaching

SO: A: Best Paper, honor graduation, member of 2 Honor Societies
B:Phi Beta Kappa, most promissing grad, cited for contribution to science
C:Top 5%of class, Phi B K
D:

SK: from what institutions ? TYPE FASTER TURKEY go

SO: First change above AC A, B, C to B, C, D Sorry

SK: ok go

SO: B: Grad from Duke Unev.
C: Harvard and Oxford
D:Univ. of Montana, Cornell
E:U. of Calif at Berkeley , UCla

Fig. 26. Start of the interchanges between two persons who communicated in the teletypewriter mode to solve a faculty selection problem. On the original protocol the seeker's messages (SK) were in black type, the source's in red. The vertical spacing has been adjusted here to make it more regular than on the original. The horizontal spacing duplicates that on the original protocol.

So: Well, it's, it's a clip now, right?

Sk: Yeah, it's a clip.

So: How how wide is the clip?

Sk: It's ah, a little bit wider than than the socket.

So: How does it fit now, does it fit...Is it go on the bottom of it or it's it's definitely parallel to it?

Sk: Right.

So: It's definitely parallel

{ So; to it?
{ Sk: It's

Sk; parallel so that when you clip it...

So: Okay I got you, but it's wider than it right?

Sk: Yeah, a little bit wider.

So: A little bit wider.....Okay wait a second. Uh how wide is the socket is it, you know the socket itself

{ So; is it/
{ Sk: Okay

So; wide or thin cause I have uh two two just about like that, what you described.

Sk: Okay now, uh there's a socket and then there's a clip...

So: I have the clip on and everything I've got that.

Sk: Right. Okay now perpendicular to the socket there are two flanges...

Fig. 27. Start of the interchanges between two persons who communicated by voice to solve the object identification problem. So refers to the source; Sk to the seeker. Braces on the left identify instances in which both source and seeker were talking at the same time. A semicolon indicates a message that continues without interruption with material above it.

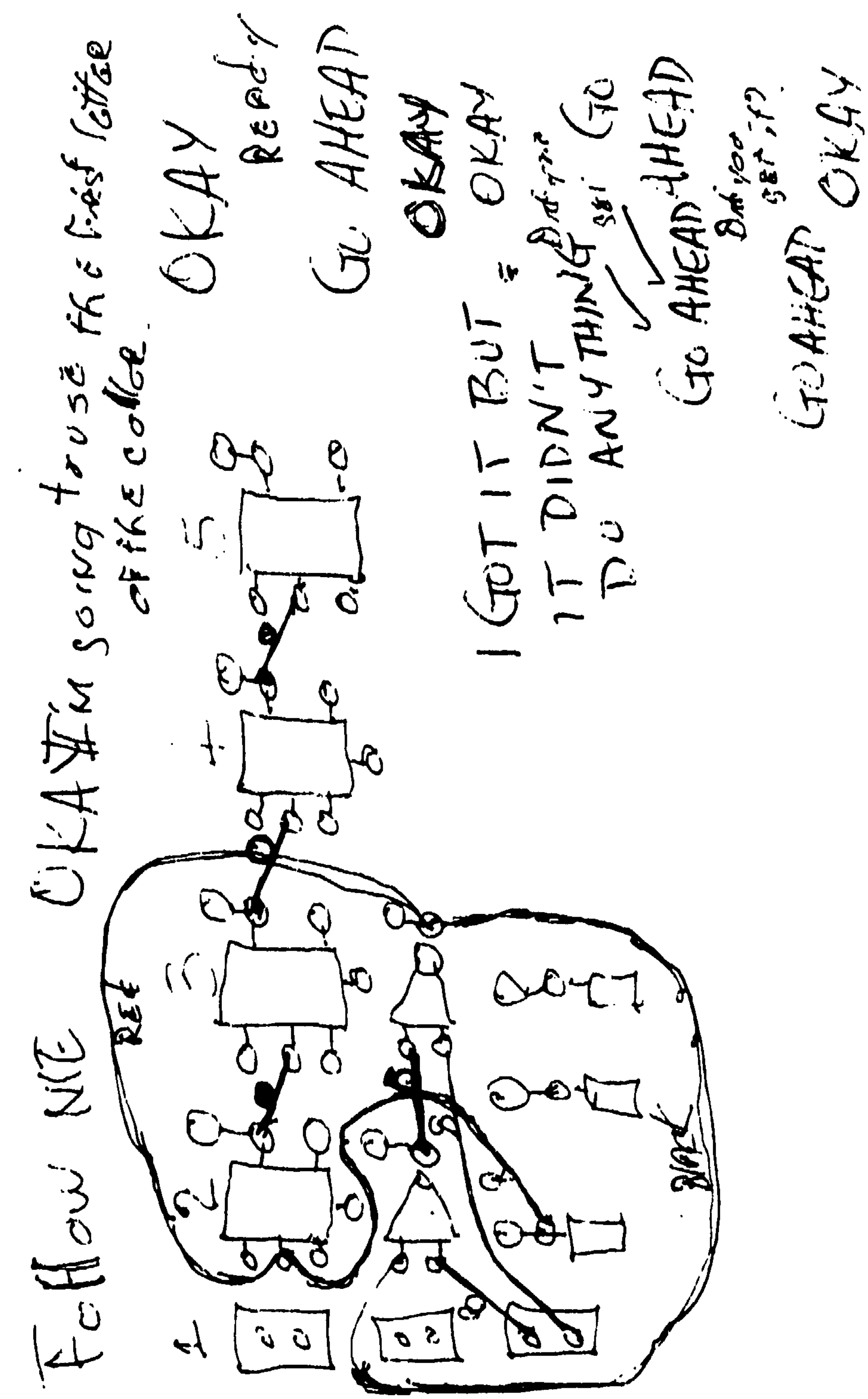


Fig. 28. One segment of a telepen protocol made by two persons who solved the wiring task illustrated in Figures 3 and 4. This black-and-white illustration does not show that messages by one person were in blue ink, by the other in red ink. Careful study will reveal, however, that there are 14 separate messages here with each communicator in turn adding to earlier messages. (From Hoecker, unpublished data)

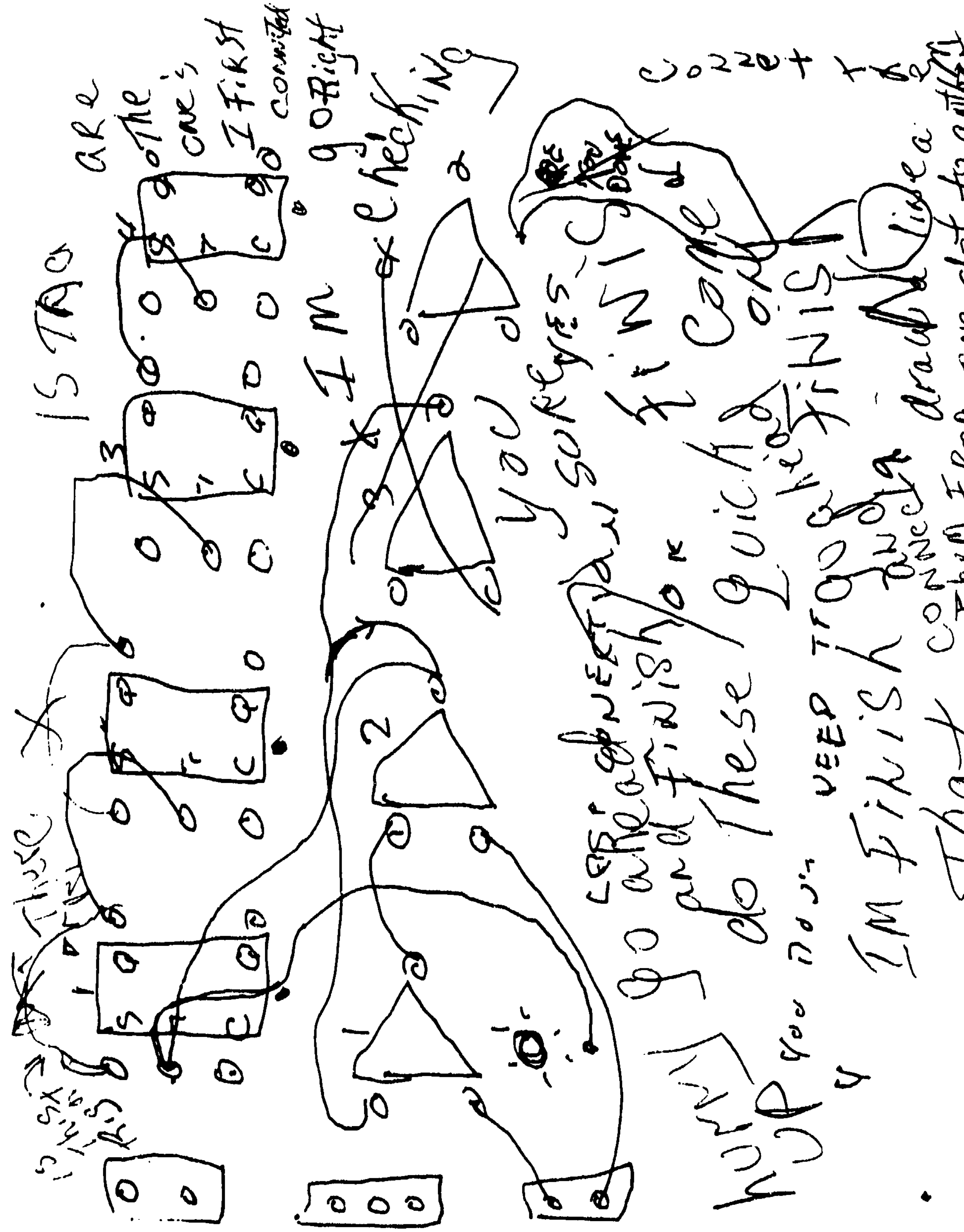


Fig. 29. A segment of an extremely disorganized protocol from the same experiment that produced the protocol in Figure 28. (From Hoecker, unpublished data)

16. Natural language communications may be described by a surprisingly short list of perhaps no more than seven linguistic measures.

In our study we defined and examined some 182 measures of linguistic performance, most of which turned out to be redundant and some of which were useless or meaningless. In the end we came up with the following list of linguistic measures that we think are meaningful for this kind of research:

1. The number of messages used by a subject, and, a measure highly correlated with that one, the number of sentences used. The former, however, is much easier to score than the latter.

2. The number of words per message, and, a measure highly correlated with that one, the number of words per sentence. The former measure, however, is much easier to score than the latter.

3. The percentage of messages that were interrupted.

4. The total number of words used by a subject.

5. The total number of unique words used by a subject.

6. The type-token ratio, that is, the ratio of 5 to 4 above.

7. Communication rate, that is, the number of words communicated per minute of time spent communicating.

In one sense, our findings are disappointing: There appears to be very little to show for so much effort. In another sense, however, they are gratifying: The linguistic performance of people who communicate naturally can be distilled to a rather small number of quantitative measures. In any case, our experience in trying to grapple with these problems will hopefully be useful to others who may try to carry on this kind of research.

I said that our work is a start and I meant precisely that. I have no illusions about what our researches have told us. It is difficult to find the rules that underlie natural human communication and we are just beginning to get an inkling of what those rules must be. There clearly must be rules, because problems get solved and get solved rather expeditiously at that. If we are ever to have computers that can interact with their human counterparts in natural

English, by typewriter, by voice, or by handwriting, we will somehow have to discover at least some of the rules that apply to natural, unconstrained communication. Discovering those rules is, in my opinion, one of the most fascinating and challenging problems facing both basic and applied scientists in this area of man-computer interaction.

Acknowledgements

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References

Berkeley, E. C. Giant brains or machines that think. New York: John Wiley and Sons, Inc., 1949.

Bush, V. As we may think. Atlantic Monthly, 1945, 176, 101-108.

Chapanis, A. Prelude to 2001: Explorations in human communication. American Psychologist, 1971, 26, 949-961.

Chapanis, A. The communication of factual information through various channels. Information Storage and Retrieval, 1973, 9, 215-231.

Chapanis, A. Interactive human communication. Scientific American, 1975, 232(3), 36-42.

Chapanis, A., Ochsman, R. B., Parrish, R. N., and Weeks, G. D. Studies in interactive communication: I. The effects of four communication modes on the behavior of teams during cooperative problem-solving. Human Factors, 1972, 14, 487-509.

Chapanis, A., and Overbey, C. M. Studies in interactive communication: III. Effects of similar and dissimilar communication channels and two interchange options on team problem solving. Perceptual and Motor Skills, 1974, 38, 343-374 (Monograph Supplement 2-V38).

Chapanis, A., Parrish, R. N., Ochsman, R. B., and Weeks, G. D. Studies in interactive communication: II. The effects of four communication modes on the linguistic performance of teams during cooperative problem solving. Human Factors, in press.

Fries, C. C. The structure of English. New York: Harcourt, Brace, 1952.

The future of computer conferencing: An interview with Murray Turoff. The Futurist, 1975, 9, 182-190 & 195.

Kelly, M. J. Studies in interactive communication: Limited vocabulary natural language dialogue (Doctoral dissertation, The Johns Hopkins University, 1975). Dissertation Abstracts International, 1976, 36, 3647B. (University Microfilms No. 76-1518)

Licklider, J. C. R. Man-computer symbiosis. IRE Transactions on Human Factors in Electronics, 1960, HFE-1, 4-11.

Licklider, J. C. R. Libraries of the future. Cambridge, Massachusetts: The M.I.T. Press, 1965.

Ochsman, R. B., and Chapanis, A. The effects of 10 communication modes on the behavior of teams during co-operative problem-solving. International Journal of Man-Machine Studies, 1974, 6, 579-619.

Parrish, R. N. Interactive communication in team problem-solving as a function of two educational levels and two communication modes. (Doctoral dissertation, The Johns Hopkins University, 1973). Dissertation Abstracts International, 1974, 34, 5721B. (University Microfilms No. 74-10, 440)

Stoll, F. C., Hoecker, D. G., Krueger, G. P., and Chapanis, A. The effects of four communication modes on the structure of language used during cooperative problem solving. Journal of Psychology, 1976, in press.

Turing, A. M. Computing machinery and intelligence. Mind, 1950, 59, 433-460.

Weeks, G. D., and Chapanis, A. Cooperative versus conflictive problem solving in three telecommunication modes. Perceptual and Motor Skills, 1976, 42, 879-917.

Weeks, G. D., Kelly, M. J., and Chapanis, A. Studies in interactive communication: V. Cooperative problem solving by skilled and unskilled typists in a teletypewriter mode. Journal of Applied Psychology, 1974, 59, 665-674.

Weizenbaum, J. Contextual understanding by computers. In Z. W. Pylyshyn (Ed.), Perspectives on the computer revolution. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970.

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