WORDS, WORDS, WORDS

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The aim of this paper is to call to attention a very large and important area of human factors engineering that is almost entirely neglected. This area consists of the language and the words that are attached to the tools, machines, systems, and operations with which human factors engineers are concerned. Examples, illustrations, and data are cited to show that changes in the words used in man-machine systems may produce greater improvements in performance than human engineering changes in the machine itself. Argument are made that this province – the language and words of machines – is properly the concern of the human factors engineer, and not of the grammarian, linguist, or the communication theorist. The paper concludes with an outline of some of the kinds of work that needs to be done to fill these important gaps in our knowledge and technology.

INTRODUCTION

In the opening scene of one of Shakespeare's great tragedies, we find the castle Elsinore haunted by a strange and fearsome specter. When news of this apparition is brought to Prince Hamlet, the prince himself decides to take up a watch on the battlements one night. There at midnight he is confronted by a ghost which draws him off to one side and reveals that it is the spirit of Hamlet's recently deceased father. Hamlet's terror turns to horror when the phantom tells him that his father was murdered by his brother, Hamlet's uncle, a man who not only usurped the throne but married the recently widowed queen, Hamlet's mother. Before he disappears, the ghost exhorts the prince to avenge this foul deed. In the days that follow, Hamlet is beside himself with anguish. The king and queen, concerned about his obvious distress, ask the lord chamberlain, Polonius, to see if he can discover the reason for Hamlet's strange behavior. Polonius meets the prince in the lobby and asks him, "What do you read, my lord?" To which Hamlet replies, "Words, words, words."

In this skillfully written exchange Shakespeare cleverly creates the impression of a man who reads, but who doesn't grasp what he reads. I, too, want to talk to you today about words – about words that we all read. I hope that, like Shakespeare, I can also convey unmistakably the idea that we often do not grasp what we read. But there, I am afraid, the comparison ends. Our purposes are different – Shakespeare's and mine. Hamlet didn't understand what he was reading because of his own state of mind – because of the turmoil in the mind of the man who was reading the words. I, on the other hand, want to talk to you about words that we do not understand because of the untidiness in the minds of the people who wrote the words.

A PREVIEW OF THINGS TO COME

The main purpose of this work is to call attention to a very large and important area of human factors engineering that remains almost entirely neglected. This area consists of the language and the words that are attached to the tools, machines, systems, and operations with which we are concerned. Using examples, illustrations, and data, I seek to show how changes in the words that are used in human-machines systems may actually produce greater improvements in performance than human engineering changes in the machine itself. I argue that this province – the words and language of machine systems – is properly the concern of the human factors engineer, and not of the grammarian, the linguist, or the communication theorist. Finally, I will discuss some of the kinds of work that needs to be done to fill these important gaps in our knowledge and technology.

Before I launch into the mainstream of my argument, I want to make it clear that I shall be talking about problems of communication. The problems of communication about which I shall talk, however, are problems that cannot be solved, or even understood, by so-called communication theory. I am not concerned with artificial bits of what some mathematicians choose to call information. I am concerned with transmission of ideas and understanding – of meanings which result in concrete human actions. These have not yet been reduced to the primitive language of the computer.

WHY STUDY WORDS?

Why should we study words? There are many answers to this question. Three, however, appeal to me.

Language Is a Uniquely Human Activity

The first reason why the study of language is so interesting to me is that it is a distinctly human activity. I realize, of course, that in making this statement I may expect shouts of protest from animal psychologists who will call to my attention the language of the bees, the articulations of the great and lesser apes, and so on. Nonetheless, my statement still stands. Human beings are is the only living organisms that use a written, codified, symbolic language to communicate ideas and to transmit the accumulated wealth of culture over enormous distances of time and space. As compared with the richness, depth, and complexity of human language, the communications of infra-human organisms are just so much inconsequential babbling. Let me now remind you that we call our field *human* factors engineering and that we use the adjective *human* deliberately. In a general sense, then, I think the study of language is an appropriate activity for us because we are concerned with human factors and because language is a uniquely human factor.

We Are Surrounded by Words

As human factors engineers, we usually think of ourselves as being primarily preoccupied with machines. I submit that this is wrong. The basic stuff with which we deal is not machines, but words. Like it or not, we are surrounded by words. We use far more words than machines, and, in fact, our principal end product is words. Let's take a minute to survey the size of the problem.

The contents of the world's libraries. What do you think is the total number of different volumes available to the avid reader? This is relatively easy to estimate if we confine ourselves to the United States. In 1958, for example, the Library of Congress held some 11,000,000 different volumes. However, the total number of all its holdings (pamphlets, journals, maps, technical reports, and so on) was 3.5 times the number of its volumes. Thus, we may take as a first approximation that in 1958 the Library of Congress had something on the order of 38,500,000 different *things*. Estimates of the total contents of the world's libraries are somewhat more difficult to arrive at, but Senders (1963) has provided us with some usable figures. He made six different estimates, arrived at by using essentially three different lines of reasoning. We need not be too concerned about the steps in his logic but may note that his six values come out to be within roughly one order of magnitude. Using his most extreme values, it appears that there are most likely between 75,000,000 and 770,000,000 different *things* in all the libraries of the world.

At the present time, new additions to the Library of Congress each year are made at a rate of about 3.1% of its holdings. If we can assume that this same figure holds throughout the world, then approximately 7,000,000 new items are being added to the libraries of the world each year. At this rate the contents of the world's libraries will double in about 22 years.

The periodical literature of the world. In arriving at his estimates, Senders counted journals as volumes and did not consider the articles contained in those journals. There are, however, about 30,000 to 35,000 scientific and technical journals being published throughout the world today and these journals contain between one and two million articles each year (Bourne, 1962). Psychology, with an output of about 12,000 articles in some 500 or 600 journals, contributes a very small fraction of this total. The aero-space sciences, for example, can claim about 1,500 journals with an annual output of perhaps 45,000 articles. The field of electronics and electrical engineering contributes about an equal amount. All of these are rather trivial as compared with such wordy disciplines as chemistry, biology, agriculture, and medicine. Medical articles appear at a rate of nearly a quarter of a million a year in about 9,000 journals.

But enough of these dry statistics. Perhaps by now I have been able to convince you that in our science and technology we are being deluged with a frightening avalanche of words. Brian Shackel has computed that it takes 5% of an average human engineer's working time just to scan systematically the abstracts on ergonomics that are published periodically by the Warren Spring Laboratories in Great Britain. A compulsive, well-versed human engineer would have to read, I suppose, something on the order of 20 to 30 articles, books, theses, and technical reports every day of the year merely to keep abreast of the current literature, much less catch up with things that have been published in the past. This is already a problem of frightening proportions. And the worst is yet to come!

Machines Cannot Be Operated Without Words

The third reason we should be concerned with words is that our modern-day machines literally cannot be operated without them. In the early days of our industrial civilization it was possible for an immigrant worker to learn a machine operation by gestures or by imitation. Those days are gone forever. Can you imagine trying to teach someone to fly a jet aircraft, program a digital computer, or use a height-finding radar, without any written or spoken words at all?

You have heard many times, I know, that a second industrial revolution is largely responsible for the growth of human factors engineering. That revolution is usually traced to the appearance of machines and machine systems which dealt, not with concrete products like glass bottles, steel ingots, and washing machines, but with information – meaningful information which can be understood, handled, and transferred from man to machine and vice versa, only by words. I shall have more specific documentation on this point later. For the time being, let me simply state categorically that words are the proper concern of the human factors engineer because they have become absolutely indispensable in learning to operate, and in operating, the intricate machine systems with which we are all concerned.

SOME WORD PROBLEMS

Having talked about three general reasons why human factors engineers should be concerned with language, let me turn now to some of the problems that words create in our man-machine civilization. My aim at this point is to be detailed and specific, and to document the problems I see with genuine examples from the machine world around us.

The Words of Documents

The foremost, and most widespread word problem in human factors engineering is the language of human engineering itself. Many of the documents we read and write are, to be blunt, atrocious pieces of composition. There is so much verbosity, pomposity, and obscurity in the human engineering literature today that it is a wonder much of it ever gets read at all. The examples one could cite are almost endless. The two which follow are a couple I came across recently. Both, incidentally, were written for military audiences.

> 1. The problem of test data validity demands attention throughout the series of events marking the development, execution, and analysis of a test. Ideally, the problem is recognized during the development of the test plan and test operations are structured accordingly. In "worst case" situations the problem of test data validity assurance remains implicit throughout planning stages and test operations as well. In the worst case, realization of the necessity for data validity arrives after the testing fact and the data, if not useless and incapable of interpretation, are likely to respond only to the utmost analytical artistry to provide trivial conclusions.
>
> 2. The concept is that of an appreciative continuum with meaning carried forward in immediate memory from moment to moment – perception being born of perception in such manner that repeated experience with instances of classes of objects and events generate schemes of likenesses and preconceptualizing hypotheses whereby on succeeding occasions the known instances are observed less in their unique character and more as contextual relative – that is, as things incidentally noted as being what they are in the places and at the times they are supposed to be, in the service of purposes deriving out of the past and projecting into the future.

How much information do you suppose these two writers managed to convey to their audiences? There's a curious superstition prevalent about technical writing. Many people believe that difficult or obscure writing is the mark of a learned man. In actual fact the reverse is true. Anyone can be obscure an incoherent. This takes no effort whatsoever. But to write technical material simply – that takes real skill! Moreover, before you can write easily you have to have absolute and complete mastery of your subject matter. That, unfortunately, is what we so commonly lack. Much of what passes for profundity in writing may well be only a reflection of cloudiness in the mind of the writer.

Let me contrast the two pieces of writing above with a beautiful passage written by one of the outstanding scientists of our time. In writing about scientific communication, he says, "When we tell about our work, we explain what we have done and we tell what we have seen. . . ." Just listen to the almost poetic clarity of those words. They were written by Robert Oppenheimer (1963). It may very well be that Oppenheimer writes this way because of what he learned from an illustrious teacher, Paul Dirac, recipient of the Nobel Prize and several other distinguished awards. Oppenheimer recalls that Dirac once said to him, "In physics we try to say things that no one knew before in a way that everyone can understand. . . ."

Speeches like mine are, fortunately, transitory. Within a fraction of a second after I have uttered my words, the sound waves disappear and are gone forever. Written communications, unfortunately, appear as hard copies. Badly written articles, technical reports, and documents stay on as durable and stable monuments of obfuscation that confuse and baffle uncounted numbers of readers for years and years to come. I wonder how many man-hours of reading time could be saved for all the scientists and professional people of the world if we all followed Dirac's dictum and tried to say things in a way that everyone can understand.

I'm afraid, however, that we have here a situation much like that in the delightful story Higham (1957) tells about Dr. Hastings Rashdall, a celebrated authority on Canon law and medieval universities. Although a scholar of substantial renown, Dr. Rashdall's understanding of modern machinery was childlike. One day the front tire of his bicycle went flat, and the venerable dean started pumping up the back one vigorously. When a passerby pointed out the futility of this procedure, the professor is said to have exclaimed, "*What! Do they not communicate*?" Some of our problems of modern-day communication appear to be of this nature. Many of us are pumping out words in great profusion from the back ends of our institutions hoping that somehow the information will penetrate to the people that need it. This, I am afraid, is not good enough. In my opinion, one of the most pressing problems in human engineering today is the need to human engineer the literature of our field. Improving the readability of our written documents is, of course, not a problem unique to the field of human factors engineering. It's everyone's problem. Although there's a lot more one could say about it, I want to turn now to some problems which do belong to us, and to us alone.

Machines and Their Words

One way of defining human factors engineering is to say that we try to design machines and jobs so that people can use the machines, and do the jobs, safely and efficiently. If you can accept this definition or one similar to it, then it is also part of our business to design the instructions that go with jobs, the labels which are attached to machines, and the signs that direct us what to do. Look around carefully, however, and you will soon find many instructions that do not instruct and directions that do not direct. Let me take some specific examples.

Confusion at the elevators. Figure 1 illustrates a problem that arose in a very large building in Baltimore. You see in this figure two elevator doors and some signs between them. Figure 2 focuses more closely on one of those signs. What does this sign direct you to do? In a small study I did on this sign, I discovered that most people think something along these lines: "This must be one of those fancy new elevators that has something automatic. The elevator doesn't stop at this floor very often. If I want to get the elevator I'd better go up one floor or go down two floors." And this, in actual fact, is what many people did. When they had trudged either up or down, however, they found exactly the same sign at their destination.

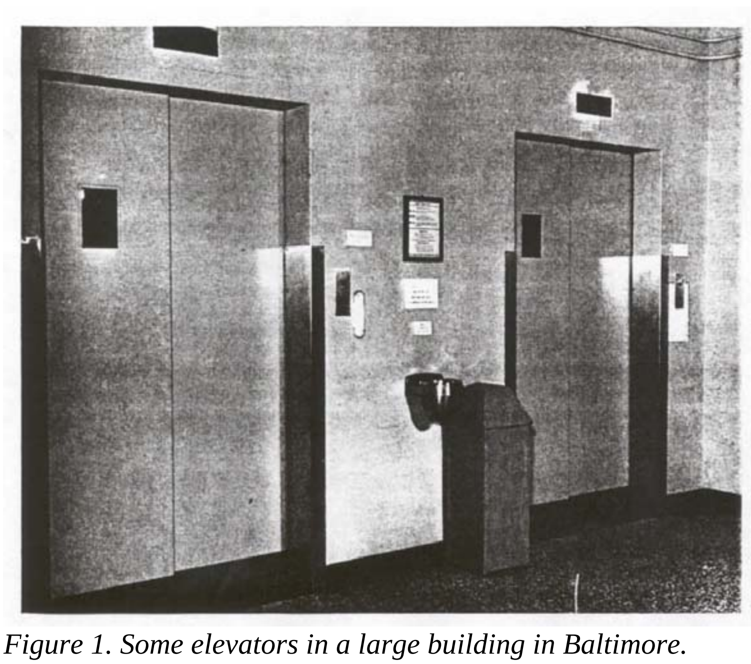


Figure 1. Some elevators in a large building in Baltimore.

Figure 2. A notice posted between the two elevator doors shown in Fig. 1.

Figure 3 tries to clarify this situation. Let me end my remarks on this case study be telling you that these elevators are located in a very large hospital and that these signs appear in many places throughout the building. Let me tell you also that identical signs appear in at least one other very large public building in the same city.

Figure 3. Some alternative wording for the notice in Fig. 2.

Lamps that do what? My next illustration (Figure 4) is somewhat different. It is a label attached to an expensive AM-FM radio. In the sample of people I tested with this specimen, the first reaction was usually one of bewilderment: What does a long life pilot lamp have to do with staying on a short time? Figure 5 suggests some other wording that might perhaps do a better job.

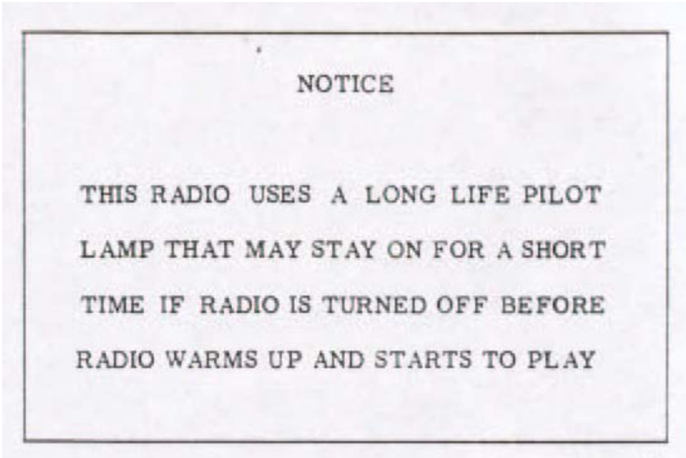


Figure 4. A notice attached to an AM-FM radio.

What paint goes where? My next illustration is the result of a little espionage work done for me by one of my agents. Although I shall describe it only in general terms, the illustration is true enough, I assure you. There is a very large device, part of which might even look like what I show you here as Figure 6. When I say large, I mean that I suppose a man could, if he wanted to, crawl into this container easily. It so happens that parts of this thing need to be carefully shielded against some severe environmental stresses – extreme heat being one of them. Sprays are applied to protect this gadget and these sprays are called finishers.

This thing was designed to be transported to a paint shop with some instructions – part of which appear in Figure 7. Let’s look at one of these instructions: “Finish 198 all over but may have 684B on areas designated . . . with an X.” Looks simple enough, doesn’t it? But look again. Exactly what is the man in the paint shop supposed to do? Four interpretations I got in a small opinion survey are shown in Figure 8. Perhaps you will understand why this set of instructions caused some consternation. What would you do if you were faced with these words?

What it said: (29 words)	NOTICE THIS RADIO USES A LONG LIFE PILOT LAMP THAT MAY STAY ON FOR A SHORT TIME IF RADIO IS TURNED OFF BEFORE RADIO WARMS UP AND STARTS TO PLAY
What is meant: (19 words)	NOTICE DON'T WORRY IF THE PILOT LAMP SHOULD STAY ON FOR A LITTLE WHILE AFTER YOU TURN THE RADIO OFF
This is more accurate: (21 words)	NOTICE IF YOU TURN THE RADIO ON, AND THEN OFF RIGHT AWAY, THE PILOT LAMP MAY STAY ON FOR A LITTLE WHILE
But would this do? (16 words)	NOTICE THE PILOT LAMP SOMETIMES STAYS ON FOR A LITTLE WHILE AFTER YOU TURN THE RADIO OFF

Figure 5. Some alternative wording for the notice in Fig. 4.

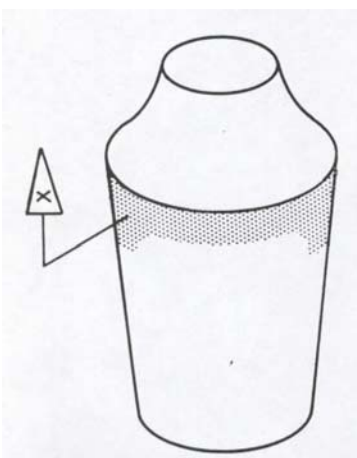


Figure 6. A schematic illustration of a large device to be sprayed with protective finishes.

Translations into common speech. When I was at the U.S. Army Electronic Proving Ground in Fort Hauchuca, Arizona, recently, I saw a number of instruction manuals written for various pieces of electronic equipment. Most of these were, in my opinion, well beyond the audience for which they were intended. The soldiers' solution to this difficulty was something simple and effective: They translated the instructions to meet their needs. Let me give you an example. The instructions for one item contained this sentence: "WARNING: The batteries in the AN/MSQ-55 could be a lethal source of electrical power under certain conditions."

On the equipment itself, however, next to the terminals there was a slip of paper on which someone had printed in large red letters: “LOOK OUT! THIS CAN KILL YOU!”

What a marvelous job of translation this is! Some unknown soldier had cut through the insipid statement that the “batteries . . . could be a lethal source of electrical power under certain conditions” and had extracted the heart of the idea: “This can kill you.” He used just four words, each a single syllable, blunt, clear, and to the point.

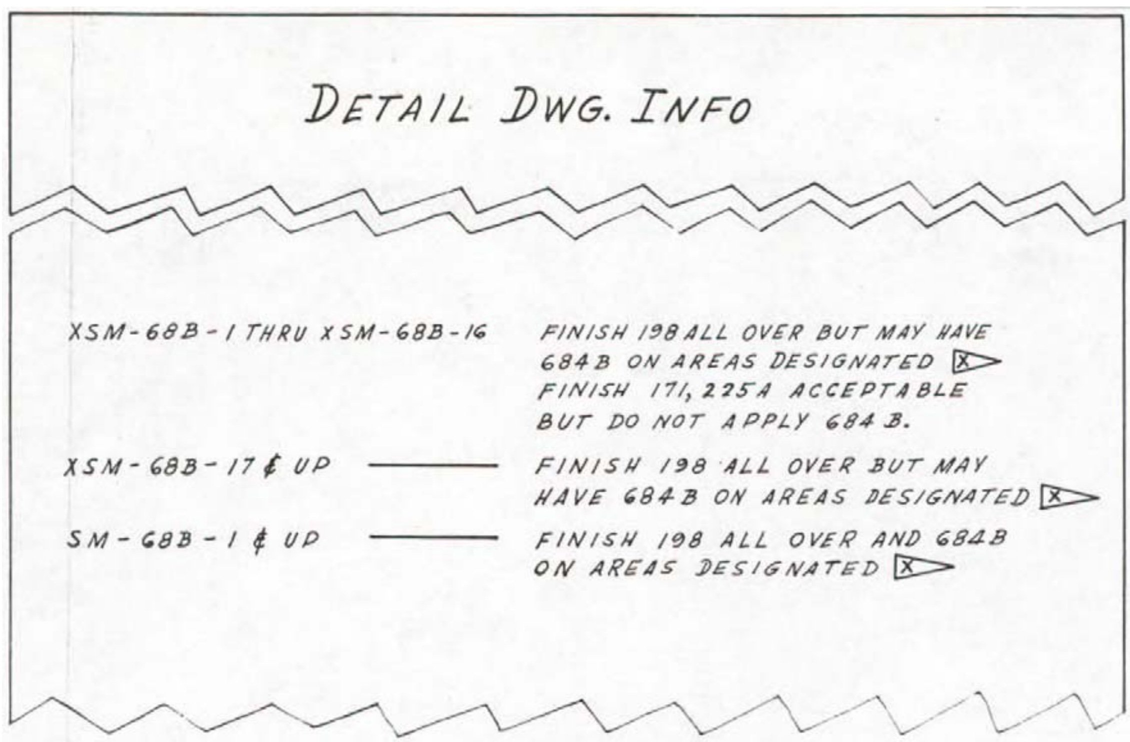


Figure 7. The designer’s instructions for the device illustrated in Fig. 6.

<u>WHAT</u> <u>IT</u> <u>SAYS</u>:

Finish 198 all over but may have 684B on areas designated .

<u>WHAT</u> <u>IT</u> <u>COULD</u> <u>MEAN</u>:

1. Finish 198 or 684B on areas marked ; 198 everywhere else.
2. Finish 198 all over even if 684B was applied first on areas marked .
3. Finish 198 all over first. 684B optional afterwards on areas marked .
4. Finish 684B first on areas marked . Then 198 all over.

Figure 8. Some interpretations of the instructions illustrated in Fig. 7.

With regard to Figure 8, the designer intended the men in the paint shop to take the action indicated by alternative 4.

The designer’s instructions for calibrating another piece of electronic gear started out with a sentence of some 30 words. In the trailer which housed the equipment, I found a sheet of paper fastened to the device with a piece of adhesive tape. Penciled on the sheet of paper in large bold letters were some instructions which began this way: “1. Turn the big black knob OFF.” Here again some anonymous soldiers had taken the designer's instruction and had translated it into beautifully clear and basic English – each word a monosyllable – each word within the vocabulary of a first- or second-grade child.

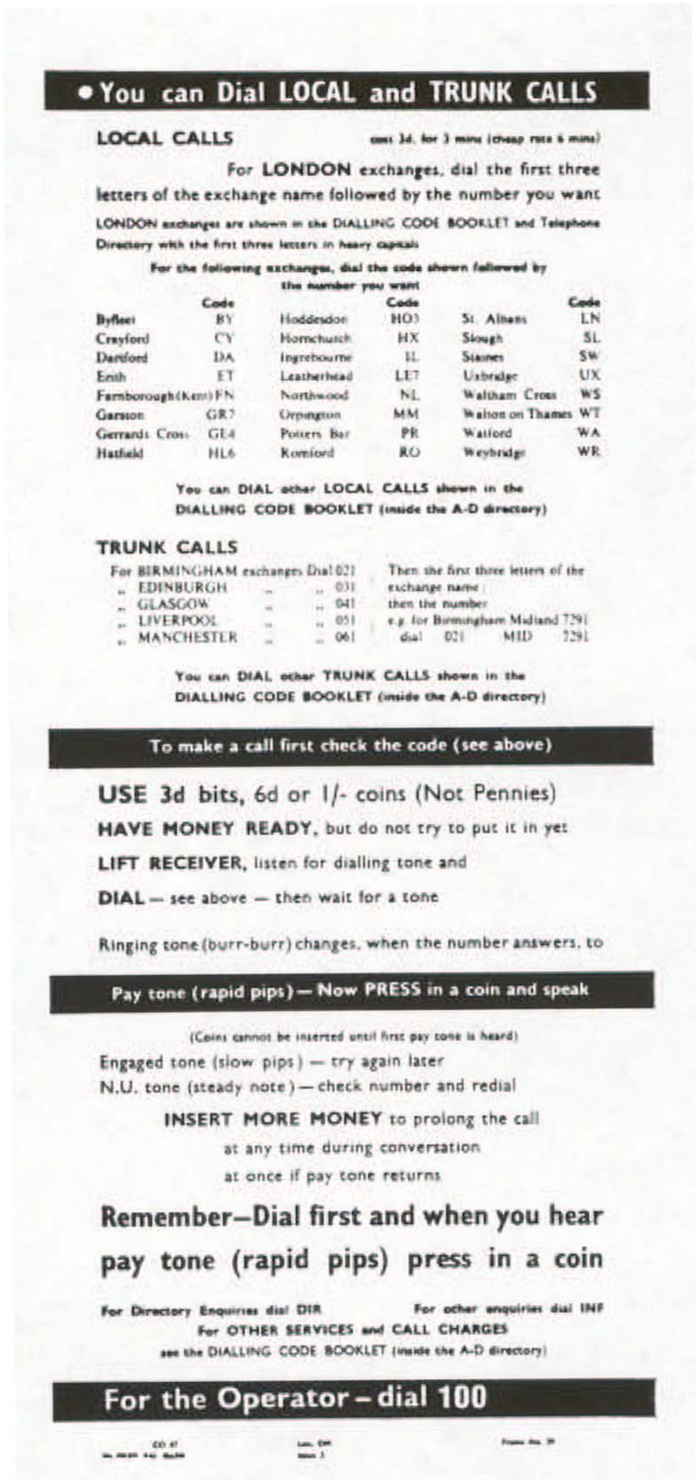
I think examples like these contain a sharp lesson for all of us – a lesson we should not and cannot ignore. Obviously, I am not suggesting that we always write in a style suitable for first- and second-grade children. What I am suggesting, however, is that there may be many times when we should write as simply as we know how. Don't forget that what you and I consider to be a simple style of writing may well be extremely difficult for a large segment of our reading public. Let me remind you that, according to the National EducationAssociation, in 1960 the median adult in the United States had completed only 11 years of schooling. When you write for high school graduates you are already writing for a select minority of our adult population.

Research on instructions. If, as good human engineers, you turn to the literature to see what research can tell you, you find pitifully little. Klare's recent book, *The Measurement of Readability,* (1963) is an excellent summary of the current status of this field. Yet among the 482 items in his bibliography there are, at most, only three items which are even indirectly concerned with the kind of thing I have been talking about today. Most readability research is, unfortunately, directed toward the readability of prose material, especially that in textbooks. None of it asks the practical question: What kind of specific human action will a person take when he reads this instruction?

The only study I have been able to find which bears directly on our problem is one by Conrad (1962) – an article published after Klare's bibliography was compiled. In introducing his study, Conrad reports that a boy in Britain was discovered frozen to death. The reason a search party had not been sent out sooner was that neither the boy's mother nor any of her neighbors knew how to use the public telephone at the end of the street. Perhaps you will understand how this could happen when you see the instructions that are placed next to the telephones (Figure 9).

Conrad was impressed by the difficulty of interpreting a set of instructions which came with a new private telephone network installed in his laboratory. His experiment was concerned with only one operation, that of transferring a call from outside the building to another person inside the building without going through the operator in the office. Four matched groups of 20 subjects each were used. Group A (Figure 10) was asked to transfer a call using the printed instruction provided by the British Post Office. As you see, only about 20% of the subjects were able to do this correctly.

Since it was conceivable that the printing itself was difficult to read, Conrad had the instruction retyped in very large, clear type and with more spacing between the lines. Group B received these reprinted instructions and, as you see from Figure 10, there was indeed a small increase in the number of people who could perform the task. Group C, however, received a shortened and rewritten version of the instructions, while Group D received instructions containing the same number of words as the original but with certain key sentences rearranged. Both sets of new instructions resulted in a marked increase in the number of people who could do the task correctly. Note, too, that the increase in performance brought about by the revision in the instructions is far greater than that resulting from mechanical changes in typography.



• You can Dial LOCAL and TRUNK CALLS

LOCAL CALLS cost 3d. for 3 mins (cheap rate 6 mins)

For **LONDON** exchanges, dial the first three letters of the exchange name followed by the number you want

LONDON exchanges are shown in the DIALLING CODE BOOKLET and Telephone Directory with the first three letters in heavy capitals

For the following exchanges, dial the code shown followed by the number you want

	Code		Code		Code
Byfleet	BY	Hoddesdon	HO3	St. Albans	LN
Crayford	CY	Hornchurch	HX	Slough	SL
Dartford	DA	Ingrebourne	IL	Staines	SW
Erith	ET	Leatherhead	LE7	Uxbridge	UX
Farnborough (Kent)	FN	Northwood	NL	Waltham Cross	WS
Garston	GR7	Orpington	MM	Walton on Thames	WT
Gerrards Cross	GE4	Potters Bar	PR	Watford	WA
Hatfield	HL6	Romford	RO	Weybridge	WR

You can DIAL other LOCAL CALLS shown in the DIALLING CODE BOOKLET (inside the A-D directory)

TRUNK CALLS

For BIRMINGHAM exchanges Dial 021
„ EDINBURGH „ „ 031
„ GLASGOW „ „ 041
„ LIVERPOOL „ „ 051
„ MANCHESTER „ „ 061

Then the first three letters of the exchange name
then the number
e.g. for Birmingham Midland 7291
dial 021 MID 7291

You can DIAL other TRUNK CALLS shown in the DIALLING CODE BOOKLET (inside the A-D directory)

To make a call first check the code (see above)

USE 3d bits, 6d or 1/- coins (Not Pennies)

HAVE MONEY READY, but do not try to put it in yet

LIFT RECEIVER, listen for dialling tone and

DIAL — see above — then wait for a tone

Ringing tone (burr-burr) changes, when the number answers, to

Pay tone (rapid pips) — Now PRESS in a coin and speak

(Coins cannot be inserted until first pay tone is heard)

Engaged tone (slow pips) — try again later
N.U. tone (steady note) — check number and redial

INSERT MORE MONEY to prolong the call
at any time during conversation
at once if pay tone returns

Remember—Dial first and when you hear pay tone (rapid pips) press in a coin

For Directory Enquiries dial DIR For other enquiries dial INF
For OTHER SERVICES and CALL CHARGES
see the DIALLING CODE BOOKLET (inside the A-D directory)

For the Operator – dial 100

Figure 9. Instructions posted alongside pay telephones in Great Britain.

Insufficient instructions. It is possible, of course, for instructions to be bad not because they are obscure or confusing but because they are too brief. Figure 11 shows the back end of a fairly common type of accurate electronic counter. Notice that there are eight electrical terminals on the upper end of the panel. Numbers 1 and 2 are labeled “TIME”, numbers 3 and 4 “EVENTS”, numbers 5 and 6 “OUTPUT”, and numbers 7 and 8 “RESET.” Now look at the instructions printed on the lower part of the panel. These, incidentally are the only instructions printed on the counter. You see that one fairly short, clear sentence says: “To measure intervals of time, connect terminal 1 to terminal 2.” If one followed these instructions precisely, would he be measuring intervals of time? Not at all. In fact, if you connect these two terminals with a jumper wire, plug the counter in to a wall outlet, and flip the main switch (on the front side of the counter and so not shown here) ON, nothing happens except that the counter tubes light up. Clearly something more is necessary.

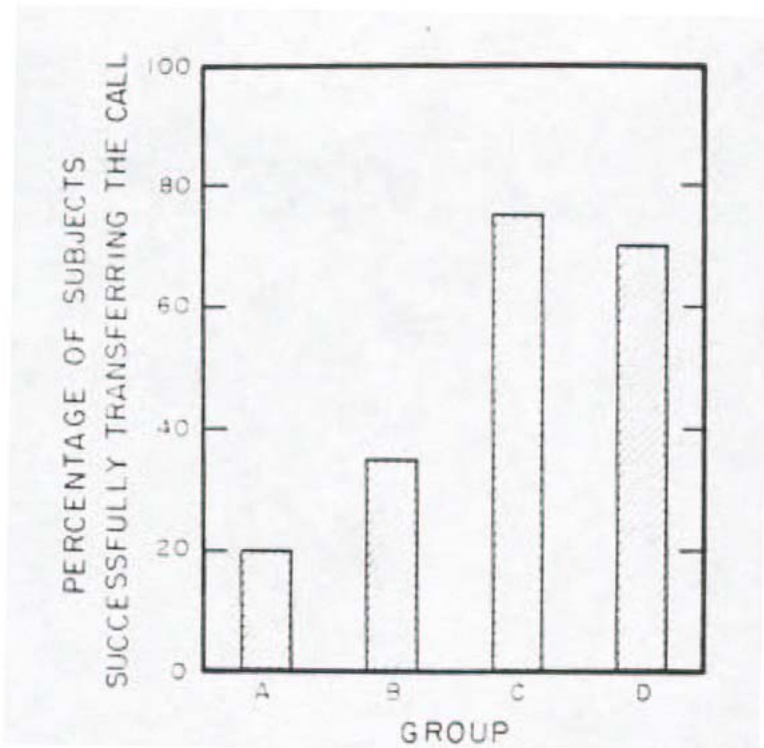


Figure 10. Results of Conrad’s experiment on the design of information for a small telephone system.

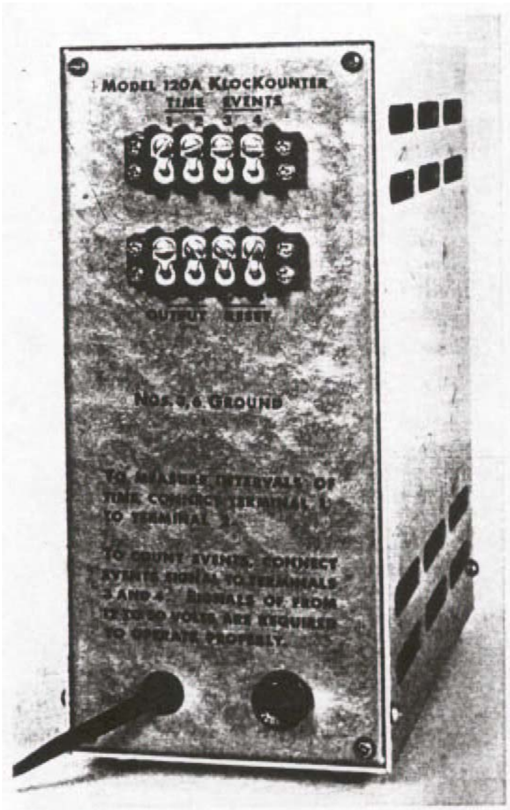


Figure 11. The back end of an accurate electronic counter.

It turns out that intervals of time can be measured in three distinct ways. The simplest way of using this device is to plug it into an electrical outlet and have it measure time continuously, just as an ordinary electric clock measures time in your home. To use the counter in this simple way, however, you must also connect terminal 7 to terminal 8, a fact which is cleverly omitted from the instructions.

In actual practice psychologists, or human engineers, would almost never want to use the counter in the simple way described above. Most commonly they would want to measure the length of time that a circuit has been closed (as in reaction time studies, for example). To use the counter in this way, it turns out that one must actually remove the shorting wire from terminals 1 and 2 and connect the circuit to be timed across these same two terminals. Notice that in this case one must actually do the reverse of what the instructions say. Finally, if one wants to measure the length of time that a circuit is open, he must connect a shoring wire across terminals 1 and 2, and connect the circuit to be timed between terminals 1 and 6.

Although I shall not dwell on this point, I will mention in passing that the instructions for counting events (shown in Figure 11) are also incomplete. I think you will agree that the set of instructions illustrated in Figure 11 is clear enough as it stands, that is, the words themselves are clear. But I think you will also agree that these instructions are woefully inadequate in terms of their primary purpose, namely, that of instructing or informing the user about what he is supposed to do.

The Babel of Tongues

I want now to turn to just one more kind of problem in man-machine system design. It took World War II, the United Nations, NATO, and the balance-of-payments deficit, to bring the United States out of its isolation and into the community of nations that make up our world. This entrance into the larger affairs of the world has led to another language problem – and one about which human factors engineers have done virtually nothing.

Americans are notoriously illiterate in languages other than their own. They never had to be otherwise – until now. But when American arms, planes, tractors, trucks, and digital computers started appearing in such places as Greece, Turkey, India, Japan, Indonesia, and Korea, we suddenly discovered that not everyone in the world speaks English – American English, that is. The fact of the matter is that our world contains a bewildering assortment of languages. No one really knows how many different tongues there are, but realistic estimates place that number at about 3,000! If we concentrate only on the major languages of the world, we find that 130 are used by more than 5,000,000 (Anonymous, 1964). Sixty percent of the people on the face of the earth speak some language other than the five official languages of the United Nations – English, French, Russian, Spanish, and Mandarin Chinese. To suggest how important these language problems have become, let me recall for you a bit of history.

The World War I Lafayette Escadrille. Before the United States entered World WarI, a group of spirited and chivalrous young Americans, captivated by the glamour of the new war in the air, volunteered to form an American flying unit within the French Air Service. This unit, later called the *Lafayette Escadrille,* was officially authorized on March 14, 1916. Before the United States finally entered World War I on April 6, 1917, over 200 volunteers had joined the Lafayette Escadrille.

The adventures of the first group of Americans to enter into this service make fascinating reading even today, for, as you know, their exploits form the basis of a distinguished and proud chapter in the history of American aviation. In addition to the romance, the excitement, and the awful premonitions of what this new form of warfare would eventually mean to the world, there are some useful lessons to be learned from a look backward at this bit of history. Here is a small part of a first-person account written by James Norman Hall in 1918:

> *But my chief concern, in anticipation, had been this: how were English-speaking eleves-pilotes to overcome the linguistic handicap? My uneasiness was set at rest on this first morning, when I saw how neatly most of the difficulties were overcome. Many of the Americans had [little?] knowledge of French other than that which they had acquired since entering the French service, and this, as I have already hinted, had not great utilitarian value. An interpreter had been provided for them through the generosity and kindness of the Franco-American Committee in Paris; but it was impossible for him to be everywhere at once, and much was left to their own quickness of understanding and to the ingenuity of the moniteurs. The latter, being French, were eloquent with their gestures. With the additional aid of a few English phrases which they had acquired from the Americans, [and] the simplest kind of French, they had little difficulty in making their instructions clear.*

NATO *experience in Canada.* Now contrast this World War I experience with that of the Royal Canadian Air Force (RCAF) less than 40 years later. In 1950, Canada agreed to provide aircrew training for North Atlantic Treaty Organization (NATO) member countries as part of her contribution to NATO. Between 1950 and 1970 more than 7,000 aircrew from eleven NATO countries were trained under this program. Here is one of the major findings of this experience as reported by Sloan (1962):

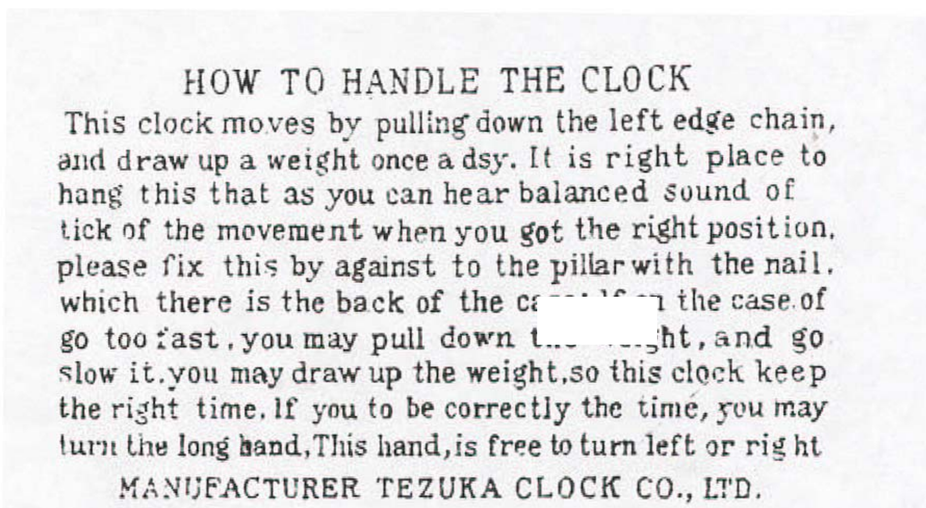
> *The fact that all training in Canada was conducted in the English language created special problems for some NATO groups. In addition to RAF students, trainees included Dutch, Danes, and Norwegians who had little difficulty with English; Belgian, French and Italian who had some degree of difficulty; and Portuguese, Greeks, and Turks to whom the English language represented serious*

problems. Prior to the opening of the RCAF NATO Language School in 1953, language was a major cause of failure at FTS [Flying Training School] for some groups. At the language school trainees were held for periods of from three to twenty weeks of intensive training in English until their proficiency was considered satisfactory for FTS training. Some trainees were repatriated directly from language school because of lack of aptitude or lack of progress in English. The school therefore served both a training and a screening function.

Let me say this another way: Instead of being the rather trivial matter it was in 1916, mastery of the language of instruction has now become the most important single determiner of success in flying school.

Some translation problems. Perhaps you will say that the problem of foreign languages is easily handled by translating the relevant material into the user's own language. The results of this simple expedient, however, are often far from satisfactory. (See Figure 12.) The example given here is highly amusing because we can see at once the absurdities in the translation. Let me assure you, however, that the amusement works both ways. Some of the instructions that we translate into French, German, Hindi, or Swahili are equally amusing. Unfortunately, to understand the humor of the translation requires a familiarity with the target language which neither you nor I have.

Let me add that I have collected stories of airplanes that have crashed, of trucks that were ruined, and of tractors that never could be used because we Americans could not communicate effectively with the people who were using, or trying to use, the machines that we produced. When you recall that American long-range jet aircraft are being used by almost every major airline of the non-communist world, you will appreciate that we do indeed have here a language problem of major proportions.



HOW TO HANDLE THE CLOCK

This clock moves by pulling down the left edge chain, and draw up a weight once a dsy. It is right place to hang this that as you can hear balanced sound of tick of the movement when you got the right position, please fix this by against to the pillar with the nail. which there is the back of the ca[illegible] the case of go too fast, you may pull down t[illegible]ght, and go slow it. you may draw up the weight, so this clock keep the right time. If you to be correctly the time, you may turn the long hand, This hand, is free to turn left or right

MANUFACTURER TEZUKA CLOCK CO., LTD.

Figure 12. Instructions provided with a clock manufactured in Japan.

Summary

In drawing this section to a close, I find that I have been able to use only a fraction of all the illustrations, examples, and data that I have accumulated preparing this work. I haven't told you about the instructions for a do-it-yourself kit that even college engineers couldn't understand. Nor have I told you about the difficulties that foreign visitors had with the signs in our New York subway system. Or the million-dollar blunder that was traced to the precise, or imprecise, definition of a single word. Or the bizarre language problems that arise in computer programming. But I hope that I have at least been able to impress upon you that language problems are prevalent in human-machine systems, that they are serious, and that they have largely been ignored. I turn now to some of the things which I think need to be done to remedy the situation.

A PROGRAM OF RESEARCH ON LANGUAGE

Trying to forecast the direction in which research will go is about as difficult as trying to forecast accurately what the weather will be like in Washington a week from now. Making statements about the way research *should go,* on the other hand, is much safer. Even so, let me assure you that I approach this with considerable inner feelings of trepidation. As I've worked in this area and studied the situation, I have become more and more impressed by the multiplicity of the problems and the scarcity of the answers. There's so much that needs to be done, it's hard to know where to begin.

One way of limiting the field of inquiry, however, is to make it clear at the start that my present interests focus on the purely practical problems of words and language that communicate meanings in human-machine systems. There is already much good work being done on language by grammarians, linguists, psychologists, cultural anthropologists, and communication theorists. By and large, however, this work strikes me as being so theoretical, or so [word missing?]oriented, that it contributes virtually nothing to the down-to-earth situations we face in machine design. To be blunt, it doesn't lead to design recommendations one can put in a human-engineering handbook or guide.

Don't misunderstand me. I believe strongly in basic research. I believe that basic research, like motherhood, holds the key to the eventual preservation and salvation of the human race. But there are times when we have to deal with problems that are here, right now, and that need to be solved today. They cannot wait for basic research. When 1,000,000 extra students show up on the doorsteps of the schools and colleges of this country, they have to be dealt with right now. It may be reassuring to know that lots of people are doing basic research on improved methods of education, but that, unfortunately, doesn't solve the problem of the kids who are hammering on the door outside.

Our language problems, I think, have this urgency. I'm delighted to know that there are people doing basic research on phonemes, bits, redundancy, semantics, pragmatics, and syntactics. But we've got a job to do. Somebody has to write that instruction manual today. We have to install that highway sign this afternoon. This label has to go on that dishwasher right now because it has to be out on the floor ready for sale tomorrow. And the Thai, Philippine, Japanese, Hindu, German, French, and Ethiopian pilots have just arrived to get training on the DC-8 and the 707 jets which their airlines bought yesterday. This is the first reason I think human factors engineers need to get into this business. Somebody has to tackle the immediate, messy problems of the real world right now. That is what engineers, human or otherwise, typically do so well.

The second reason why I think we need to get into this kind of work is that most of our problems cannot be solved by conventional methods of linguistic analysis. Instead, we need to attack these problems with the methods which we human factors engineers already know so well and use so often in our work – the critical-incident technique, methods of task analysis, and the method of experiment.

Quality Control Over the Language of Documents

I have already said that the language of our documents is everyone's problem. Because it is so universal, we already know a lot about what makes technical writing good or bad. Insofar as human factors engineering is concerned, I think the proper line of attack should be not so much in starting new research along these lines, but rather in applying what we do know. We need, in short, to institute better control over the quality of our documents.

There are a number of specific things one could do, of course. First, one could insist on a more exact definition of the target audience for each of our reports. Something that does need to be studied in this connection is the precise level and style of writing that is most efficient, most comfortable, and most acceptable to the target audiences we try to reach. The bulk of the available research on readability has been done with schoolchildren in mind. Our readers are quite different and we have practically no data on how one writes best for them. Once we had the answer to this question, contracting officers, technical directors, and editors might then insist that the language of a report be appropriate for its audience. In enforcing this insistence, I think it would be a worthwhile adventure to see many reports summarily returned to their sources with curt notes saying: "Report rejected. Too windy, too hard to read, too long. Final payment on this contract is being held up until readable report is received." Such steps would, I am sure, be highly unpopular at first. But I wonder if the long-term gain for all of us wouldn't be worth the short-term strain on some of us.

Critical-Incident Studies of Language Difficulties

The critical-incident method is a tried-and-tested technique for locating and identifying difficulties in human-machine systems. You are all familiar, I know, with the classic studies in this area which have done so much to advance our field. In preparing this work, I myself used a kind of critical-incident approach. However, my methods have been far less than systematic and my data much too scanty to dignify them with the title of research.

As a first research step into this area, therefore, I would like to see some careful and extensive critical-incident studies of language problems encountered in human-machine systems. Exactly what kinds of difficulties do people have with the words and language of human-machine systems? How extensive and widespread are these difficulties? Where should we direct other research efforts? I feel confident that this is a ripe field waiting idly to be harvested.

Criteria of Intelligibility

In his book *The Measurement of Readability*, Klare lists some 40 different formulas or techniques that have been proposed at one time or another to assess the readability of text. Unfortunately, none of them is particularly appropriate for most of the word problems we have. In the first place, the principal criteria used in validating many of the current readability formulas are: (a) speed of reading, (b) comprehension of text material as measured by tests of recall or retention, and (c) judgments of difficulty. Our interest, however, is not so much in these things as it is in the intelligibility or the understandability of what is said. It is for this reason that I deliberately say that we need formulas or techniques for measuring the intelligibility of text, rather than its readability.

A second difficulty with many current readability formulas is that they require large samples of words – as many as 1,000. Our samples of language are often short. In addition, many readability formulas depend on such things as the average length of sentences, the proportion of difficult words in the sample, or the number of affixes or suffixes in a sentence. Formulas based on counts of this type just won't work with many of our instructions. Let me illustrate.

There's nothing really difficult about any of the words in the elevator sign (Figure 2) I showed you earlier. The real problem arose because 13 short and simple words were arranged in such an order that the meaning of the ensemble was distorted. Recall also the example I gave you of the notice about the pilot lamp on the AM-FM radio (Figure 4). Twenty-two of the 29 words are monosyllables – easy words like this: *a*, *long*, and *off*, *up*, *play*, and so on. Three of the remaining seven words are *radio*[?] – certainly a commonplace word these days. The remaining four words are *uses, pilot, turned,* and *before.* You will agree, I am sure, that there isn't a hard word in the collection. But the combination is almost completely unintelligible to the average person. None of the conventional readability formulas helps us in cases like these.

Instructions built up on the basis of task analysis. As I see it, we need to have research done to discover formulas and methods for assessing the intelligibility of short declarative and imperative sentences. I am not certain in what direction we should search for these criteria, but I strongly suspect that the methods of task analysis which we have used to such great success in the design of human-machine systems may be of use to us here. My idea is that rather than starting with words, we need to start by asking what specific human actions we want to result from a set of instructions and in what order we want these actions to occur. Then we need to compose the instructions piece by piece so that they will produce those actions and in the correct order. Building up a set of instructions in this way would, I think, clearly have avoided the obscurity of the directions written for the men in the paint shop (Figure 7).

Rules for structuring short sentences. In composing instructions we need to follow certain rules of construction. What I have in mind is something like that which Miller (1962) referred to, all too briefly, as the constituent structure of a sentence. We cannot really understand a sentence until we can make an unambiguous flow diagram of it. We need to know precisely what the subject of the sentence is, what the verb is, what adjectives modify which nouns, precisely what adverbs modify what, and so on. Let me illustrate with a specific example: Long strings of four or more nouns, one right after the other, are one of the most common faults in military and technical writing today. The trouble with such sequences is that it is usually hard for the reader to figure out which of the words are supposed to be adjectives, and which are supposed to subjects or objects. The writer, of course, doesn't have this difficulty, because when he wrote the sequence he knew exactly what he had in mind. The reader, unfortunately, doesn't come to the sample of writing with the writer's set, or frame of mind. Look at a portion of the first passage I quoted earlier: ". . . the problem of test data validity assurance remains . . ." A reader coming across this for the first time is brought up short. Exactly what is the object of this prepositional phrase, what is the subject of the verb remains, and which of the remaining nouns are supposed to be read as adjectives? For example, should we read this as:

a. the problem of test,

b. the problem of . . . data,

c. the problem of . . . validity, or

d. the problem of . . . assurance?

To continue, do we read this as:

a. the problem . . . remains,

b. test . . . remains,

c. data . . . remains,

d. validity . . . remains, or

e. assurance remains?

So long as questions like these arise in the reader's mind, there will be misinterpretations. Rules for avoiding pitfalls of this kind need to be discovered, tested, and codified. Or, to give this a more positive accent, we need to devise rules for composing instructions so that the flow of words matches the flow diagram of the actions (or thought processes) that we want to be taken in response to the words.

Experimental validation of principles. Next, the rules, whatever they are, need to be validated experimentally by testing them with the behavior of people, not the judgments or opinions of linguists or grammarians. What kinds of sentence structure lead to wrong actions? What kinds of sequences of words take more time to read? How are regressive eye movements and fixations in reading related to the particular arrangement of words and phrases in a sentence? These are questions for which there are virtually no experimental answers. The merest glimpse of the rich rewards that await us here, however, is suggested by a small study reported by Miller (1962). He compared the matching of simple declarative sentences with their passive forms, negative forms, and passive negative forms. On the average, simple passive sentences, like "The small boy was warned by John," took 25% more time than their corresponding active forms, "John warned the small boy." This will come as no surprise to anyone, I'm sure, but note that military writing is full of passive sentences. In fact, you usually have to look hard to find a simple active sentence in the typical military technical report.

Still, this work of Miller's is only a beginning. We need to have a lot more experimental work done with more complicated sentences. What happens when you start adding adjectives, adverbs, prepositional phrases, and clauses in various places? Above all, these questions need to be tested in terms of their effects on the behavior of ordinary people.

Along these same lines we need to test our highway signs, labels, and instructions, not with engineers, copywriters, or advertising men, but with drivers, housewives, and electricians. In this business, the empirical test of what people do with words is the one that has most often been neglected.

Checklists for Rating Manuals

Equipment evaluations usually conclude that, among other things, there are deficiencies in the instruction manual, operating manual, or maintenance manual that is attached to the equipment. It's almost a universal finding. Yet we have no good checklists, or guides, for rating manuals. There are checklists which purport to do this, I know, but all those which I have seen are almost entirely concerned with the format and mechanical details of arrangement. I have yet to see a checklist which places any emphasis on the content and understandability of the material. The need here, I think, is great. We need criteria for evaluating manuals, methods for testing them, and guides for preparing them.

Words Versus Other Symbolic Forms of Conveying Information

There is an old Chinese proverb which says "One picture is worth more than ten thousand words." I'm not sure whether this conversion factor is correct, but I think it would be worthwhile knowing approximately how much we do gain from pictures and other forms of symbols. Traffic signs in Europe don't say "Slippery when wet." They show a picture of a car skidding in a most impressive way. How much is a picture worth? When should we use pictures rather than words? What should be the mixture of pictures and words that will give us the most understandable and most readable combination? These are only a few of the questions that lie unanswered in this area. The answers, when they come, might very well help us in the solution of some of our cross-cultural language-machine problems.

New Word Lists for Many Languages

The Thorndike-Lorge word lists are already so well known and have been used so often in experimental and applied work that I scarcely need to describe them. Lists of this kind enable us to estimate more exactly the difficulty of words that are used in ordinary writing, in instruction manuals, in directions, and so on. Recall, however, that these lists were made years ago and that they were prepared for general vocabularies. We need to have these lists brought up to date and extended.

More important than merely bringing the lists up to date, however, is the need for preparing special lists for special purposes. As I see it, we need special lists for special fields; for example, electronics, human factors engineering, or psychology, and we need lists for special audiences, audiences differentiated according to nationality, educational level, intelligence, and areas of training and skills. Many of our word problems arise, I am sure, because we cannot be sure whether certain words are, or are not, likely to be within the range of comprehension of the average citizen, soldier, maintenance technician, or engineer. Thorndike did his original work with an army of student helpers over a period of years. With the digital computers we have today, compiling lists of this kind should be vastly simpler. The rewards of such work would, I think, be great.

A Language for One World

When we come to foreign languages and the problems of designing languages for machines to be used by persons of diverse nationalities, the problems loom so large that they seem almost insurmountable. One tends immediately to think of all kinds of grandiose, and impractical, schemes like constructing a universal language. Nonetheless, there are some practical beginnings that need urgently to be made. Perhaps this would be an area in which American human factors engineers might engage in cooperative research with some of their foreign colleagues.

Let me tell you an interesting fact. In preparing his book on readability, Klare could find almost nothing on the readability of languages. This is virtually a completely unexplored area. To put it another way, almost anything one did here would be interesting and worthwhile. We need new ideas, new methods, and new solutions to the language problems that arise when a person of one nationality has to learn to use, and to operate, a complex machine produced in some other country. I feel absolutely confident, however, that no one here will challenge me when I say: There must be a better way to do it!

CONCLUSION

In conclusion, there is another characteristic of words that I have entirely neglected in everything I have considered here. This is the remarkable capacity words have to excite our emotions and to produce affective reactions within us. Words make us glad; they make us sad; and they make us mad. They may make our hearts sing or make us weep with joy, love, or patriotism. Conversely, words may frustrate us, drive us to despair, and incite us to kill ourselves or each other. These affective and emotional concomitants of words also have their implications for human factors engineering – but that’s the topic for another lecture. In addition to whatever intellectual content my words here have had, I hope that they have also been able at least to interest you, perhaps to amuse you, and hopefully even to excite you. If, by some stroke of good fortune, my language has been esthetically satisfying to you I will feel richly rewarded for having written these words, words, words.

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