# VISUAL SEARCH

## The cognitive operations involved in looking for a face in a cro or a word in a list can be studied by timing the scanning proce Apparently many such operations can be carried out simultaneou

by Ulric Neisser

One of the faces in the crowd at the top of the opposite page is that of John F. Kennedy, watching a football game shortly before his inauguration. Most people find it easy to single him out by scanning the photograph quickly, with scarcely a glance at the other faces. We perform such searching and scanning operations many times a day, for example in looking up the telephone number of a Mr. Smith who lives on Fifteenth Street. There are a lot of Smiths, but it does not take long to skim down the column to the correct address; the irrelevant addresses are passed over so quickly that they seem blurred. In a sense they are not seen at all. In much the same way one sees, but does not see, dozens of hurrying figures when trying to locate a friend in a busy air terminal. And yet the context—the unfamiliar travelers, the wrong addresses, the crowd of faces surrounding Mr. Kennedy—must surely be examined if the search is to succeed. The scanner must extract enough information from the elements of the context to make sure, or at least to suggest, that they lack the properties that define the object of his search. So in a sense the context *is* seen. There are evidently intermediate stages of perception; it is not a case of "now you see it" or "now you don't" but of something in between.

104
493
762
288
844
126
925
417
338
500
675
313

**SEARCH TASK here is to find the one three-digit number that is a multiple of 7.**

The complexity of the cognitive processes operating at these stages depends on the nature of the target and the field. In one extreme case the field is empty except for the target; elementary visual mechanisms for distinguishing contrast and contour suffice to locate the parachutist against a cloudy sky in the illustration at the bottom of the opposite page. The column of numbers on this page, however, represents a very different task: the search is for the one number in the list that is a multiple of 7, and in this case the analysis required is far more than visual. It does begin with elementary discriminations of lines and curves that form a pattern, but it goes on to interpret those patterns as numbers and then to subject the numbers to a rather advanced symbolic process. The search for Mr. Smith's telephone number is at an intermediate level of complexity, somewhere between "seeing" and "reading." The information in the wrong addresses need not be processed fully; the visual pattern of the street names penetrates the nervous system only far enough so that some subsystem sensitive to "Fifteenth Street" can have an opportunity to react.

Perceptual analysis, then, has many levels. It seems to be carried out by a multitude of separate mechanisms arranged in a hierarchy, the more c mechanisms receiving as their in information that has been assi and predigested by more elem ones.

My associates and I have bee ested in visual search as a to which to investigate this hierar information-processing operation have studied processes at the level ephone-directory search: at the ary between perception and th (Our experiments have been con at the Lincoln Laboratory of the chusetts Institute of Technolo Brandeis University and at Harva versity's Center for Cognitive S with support from the National S Foundation.) By timing people scan lists of letters or words in se specified targets, we hope to learn thing about the various visual an nitive processes involved and abo they are organized and interrelat the extent that these processes form of thinking, what we mea perhaps an approximation of "th of thought."

We ask a person to scan a list, consisting of 50 items, to find a s "critical item," or target. The l generated by a computer; each a group of letters, a group of and digits or a word, all drawn dom from a pool of items with t sired characteristics. In the condition the critical item is a for example *K* in the list at in the illustration on page subject peers through a window box within which the experimen tions a list. When the subject to begin scanning, he turns a sw illuminate the list and start a tric timer. He scans the list

FAMOUS SPECTATOR at the Orange Bowl football game on [illegible]uary 2, 1961, was President-elect John F. Kennedy. The reader should have little trouble finding him but will be hard put to explain how that one face can be identified among so many.

[illegible]E PARACHUTIST can be discovered very quickly against a [illegible] but featureless sky in this photograph. Elementary visual mechanisms are all that are required in searching for any target, even a small one, that is in strong contrast to its background.

| | |
|---|---|
| EHYP | ZVMLBQ |
| SWIQ | HSQJMF |
| UFCJ | ZTJVQR |
| WBYH | RDQTFM |
| OGTX | TQVRSX |
| GWVX | MSVRQX |
| TWLN | ZHQBTL |
| XJBU | ZJTQXL |
| UDXI | LHQVXM |
| HSFP | FVQHMS |
| XSCQ | MTSDQL |
| SDJU | TZDFQB |
| PODC | QLHBMZ |
| ZVBP | QMXBJD |
| PEVZ | RVZHSQ |
| SLRA | STFMQZ |
| JCEN | RVXSQM |
| ZLRD | MQBJFT |
| XBOD | MVZXLQ |
| PHMU | RTBXQH |
| ZHFK | BLQSZX |
| PNJW | QSVFDJ |
| CQXT | FLDVZT |
| GHNR | BQHMDX |
| IXYD | BMFDQH |
| QSVB | QHLJZT |
| GUCH | TQSHRL |
| OWBN | BMQHZJ |
| BVQN | RTBJZQ |
| FOAS | FQDLXH |
| ITZN | XJHSVQ |
| VYLD | MZRJDQ |
| LRYZ | XVQRMB |
| IJXE | QMXLSD |
| RBOE | DSZHQR |
| DVUS | FJQSMV |
| BIAJ | RSBMDQ |
| ESGF | LBMQFX |
| QGZI | FDMVQJ |
| ZWNE | HQZTXB |
| QBVC | VBQSRF |
| VARP | QHSVDZ |
| LRPA | HVQBFL |
| SGHL | HSRQZV |
| MVRJ | DQVXFB |
| GADB | RXJQSM |
| PCME | MQZFVD |
| ZODW | ZJLRTQ |
| HDBR | SHMVTQ |
| BVDZ | QXFBRJ |

**THE LETTER *K*** is the target in the list at left, and the "critical item" is the one that includes it. A more difficult task is a search for an item that does *not* include a specified letter. In the list at right, for example, there is only one item that does not include a *Q*.

finds the target, then turns the swit again to stop the clock, and the expe menter records the total time requir for the search.

Not all this time, to be sure, is neede for perceptual analysis of the iten through which a person is searchin He may need some time to get starte and he certainly needs time to execu the response that stops the clock. Th complication is dealt with by havi him scan a number of lists, in each which the *K* is in an unpredictably di ferent place. The additional time neede to find a *K* that is in the 31st line rath than in the 21st can be ascribed en tirely to the visual analysis of the i tervening 10 lines.

Now, if some fixed amount of time needed for the analysis of each lin the overall duration of the search w vary as a linear function of the numb of lines involved, that is, of the actu position of the target in the list. And i fact, when position is plotted again time, the points are almost invariabl fitted well by a straight line. The grap at the top of the opposite page is typica of thousands we have obtained. The most important information to be rea from such a line is its slope, which indi cates the increase in search time require for each additional line scanned. This time per item, then, measures decisio time uncontaminated by reaction time it seems to represent a relatively direc measure of the time used in perceptua analysis.

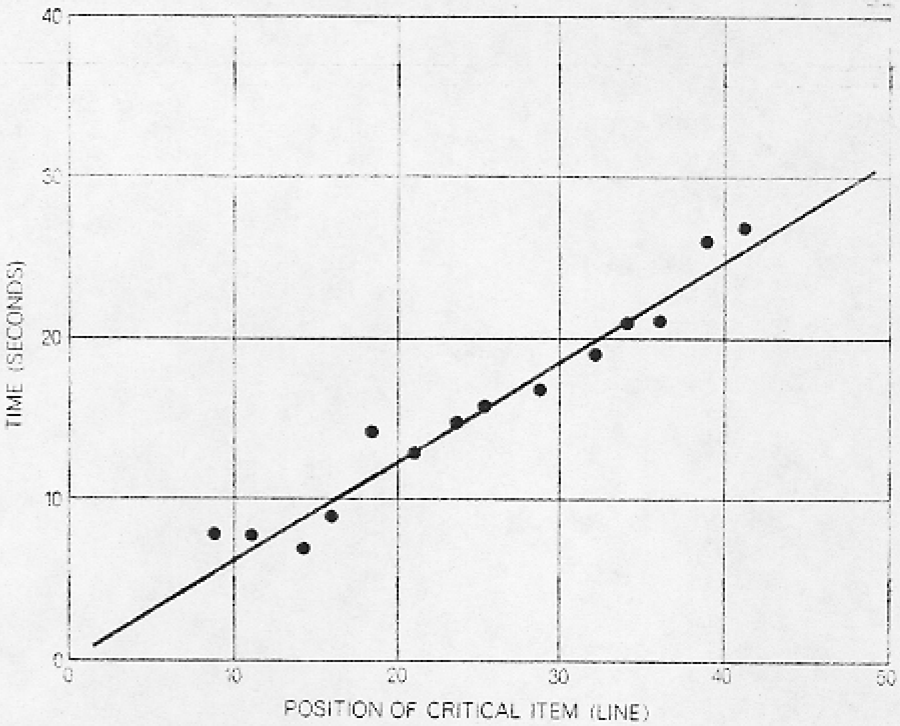
The speed with which a person sca tends to decrease dramatically during the course of a long experiment. On the first day his graph may indicate that he is using more than a second to process each line, but after two weeks of practice his time per item may well be only a tenth as long. Most subjects stabilize at about 10 lines per second with targets such as *K* and a list such as the one illustrated. This suggests plausibly enough, that most people do not enter the experiment with ready made perceptual hierarchies for finding *K*'s efficiently. They acquire—or perhaps one should say that they "construct"—a recognition system in the course of practice.

With repeated scans they discover the perceptual operations that seem to be minimally sufficient for the proble For example, some may find techniques that enable them to examine several lines at once, whereas at first they had fixated each item separately and suc cessively. For some perhaps a recheck ing procedure, involving frequent essions to preceding lines, seems lispensable at first and is dispensed ith later. Certainly the operations on ich a subject eventually settles, and manner in which he comes to adopt m, depend on many variables.

lthough this kind of perceptual learning is of great theoretical interest, course seems to be somewhat differt in each subject and we have so far nd no satisfactory way to study it. r chief interest, therefore, has been the kind of pattern analysis establed after long practice. The first estion to be asked about the modes analysis used by experienced subs concerns their thoroughness. Does subject "identify" each letter to demine if it is a *K*? The answer is alst certainly that he does not. Our viction on this point arises partly m our volunteers' reports that the ters are "not seen" or are "only a r," but even more from theoretical siderations and a further experiment. The fact is that letter identification not necessary for finding a *K*. The lysis of each line need go only far ugh to detect some of the distince features that, in various overlapg and probabilistic combinations, termine particular letters. These feaes must be characteristics of the en visual configuration: things like ticular angles, open spaces, parallines, locations of the geometric cenof gravity and so on. Rudimentary al processes that precede the idenation of letters suffice to detect such ures. (The relation of the target's figuration to that of the context ys an important role [*see illustration ight*]. Operations that suffice to disuish a Z from a set of rounded letcannot be relied on in a context of ular letters. The more extensive options needed in the latter case take e time.)

ome combination of feature-detecis presumably sufficient to penetrate nervous system far enough to stimuactivity in some subsystem sensito the letter that is sought. Other binations can activate other letters, in a one-letter search only one sysneed be allowed to proceed; activity be suppressed for all other characso that throughout the scan nothing s place at the level of letter identition until the target letter appears.

uch an interpretation of the scanprocess suggested that a search actually required the subject to tify letters in each line would be




**DURATION OF SEARCH** varies directly with the position of the critical item in the list, as shown by this graph in which position is plotted against time. The data used here were for a search by an inexperienced subject whose time per item was .62 second.

| | |
|---|---|
| ODUGQR | IVMXEW |
| QCDUGO | EWVMIX |
| CQOGRD | EXWMVI |
| QUGCDR | IXEMWV |
| URDGQO | VXWEMI |
| GRUQDO | MXVEWI |
| DUZGRO | XVWMEI |
| UCGROD | MWXVIE |
| DQRCGU | VIMEXW |
| QDOCGU | EXVWIM |
| CGUROQ | VWMIEX |
| OCDURQ | VMWIEX |
| UOCGQD | XVWMEI |
| RGQCOU | WXVEMI |
| GRUDQO | XMEWIV |
| GODUCQ | MXIVEW |
| QCURDO | VEWMIX |
| DUCOQG | EMVXWI |
| CGRDQU | IVWMEX |
| UDRCOQ | IEVMWX |
| GQCORU | WVZMXE |
| GOQUCD | XEMIWV |
| GDQUOC | WXIMEV |
| URDCGO | EMWIVX |
| GODRQC | IVEMXW |

**CONTEXT** affects the speed of a search. The letter *Z* is seen more easily against a background of generally round letters (*left*) than in a context of straight lines (*right*). Subjects found the *Z* twice as quickly in the "round" contexts as in the "angular" ones.

| | |
|---|---|
| QG17NI | JEWELS |
| Y6C1SR | ACTUAL |
| JSITO6 | OWN |
| 6GJX5R | TUNICS |
| 1JCNSY | CLUES |
| IVCYSJ | WILES |
| TRYSJ1 | PORTS |
| OSQR5V | RAGED |
| S5JWV6 | SOON |
| 5TVCWX | PHOTOS |
| Q17J5Y | GATES |
| TXCI5J | SOURED |
| 6OV1WT | PORTLY |
| RJ1CO5 | AERIAL |
| VYCJIX | QUITS |
| IY5WVX | UNDUE |
| WV51JT | COMA |
| 7WOYGJ | DRAWL |
| NQC3R1 | NASTY |
| I7W6J3 | DOPE |
| 5TJ73C | CREEPS |
| 71ITQ3 | SODA |
| CXTSO7 | SNEEZE |
| TX5V73 | LAMB |
| YBV6OJ | PUTS |
| SBONJI | MIMIC |
| CJ7WRT | SURETY |
| 17WRJ6 | FIGS |
| YGT1VJ | SANG |
| IGVTQO | CHERUB |
| 3SJTO5 | ENTRY |
| OXG3W5 | VEERED |
| YGT315 | RIFLED |
| PO3SJT | THE |
| BSTYGO | SAND |
| X1NRWB | LISTEN |
| WSCQXY | TREAD |
| V71IGB | SIZES |
| RSWX17 | SCION |
| SO65IR | TUG |
| 3GORIV | DAMPLY |
| NY17RQ | YORE |
| YG1S3B | OFFICE |
| S17NYB | ALLOWS |
| OVBQI5 | JUICY |
| V5WG3B | GAVEL |
| T5NYW6 | ELATED |
| R7GBJY | CHANGE |
| 5RSTQG | MOLDY |
| B36QIN | NIPPY |

**TEN-TARGET SEARCH** involved lists such as the one at left, in which the subject must find *A, F, K, U, 9, H, M, P, Z* or *4*. (The target happens to be *P*.) The critical item in the list at right is defined in terms of its meaning: the task is to find the name of an animal.

much slower than the search for a g letter. Such a task is exemplified at right in the illustration on page where the problem is to find a that does *not* contain a *Q*. Indeed, with extensive practice our volun never attain speeds greater than to five lines per second in such verted searches." This finding conf the view that there are distinguish levels of pattern analysis, and that m thorough analyses require more tim

One of the questions we have most anxious to investigate is the ner in which the several operations must go on at a single level of hierarchy are conducted—for exam detection of the various distinctive tures contributing to letter identi tion. Are these rudimentary operat carried out simultaneously or one time? The question can be put to test by requiring the subject to look several targets at once.

For instance, he can be presen with a list and asked to find either or a *K* without being told which of th the list actually contains. Whatever tern analysis the subject may emp during such a scan, it must surely more complex than the minimal sys needed for *K* alone. A simple assu tion would be that the search for *K* the search for *Q* proceed independen in which case hunting for both *Q* an would involve all the features nee for finding *Q* in addition to all th for *K*. Probably this is too simple one should think of the joint task as quiring only a few more compon than either problem alone.

In any case, the question is whet or not searching for two targets ta more time than searching for only o An increase in time would be consist with a hypothesis that the operations carried out in sequence, each awai the outcome of earlier ones. On the ot hand, if more operations can be p formed without an increase in time, system is at least partially parallel some level a number of "decisions" be made at once.

We began our experiments on t point rather timidly, with only two ternative targets. We were surprised find that from the very beginning practice our subjects searched as rap for either of two targets as for alone. Thus encouraged, we decided try four targets: *H, M, Q* and *Z*. subjects were first trained to search one or another of these letters indivi ally. Then they were introduced to s eral problems involving two letters

H and M. For a day or two the sub-ts scanned more slowly in the dou-e searches than in the well-practiced gle ones, but soon the difference dis-peared. At that point we introduced ts that might contain any one of the ir target letters. To our surprise the rfold search was soon going about rapidly as the others!

The information processes that detect se four letters cannot be entirely ntical, so the multiple search must olve at least some additional opera-ns that are not necessary in looking , say, the single letter Z. Our results emed to show that these extra proc-es take no extra time and so must be ultaneous with some of the Z opera-ns. It is true that the multiple scan is ically different from the single one d not simply an addition to it. Even n this point of view, however, the ference is one of complexity, and one ild expect the more complex multi-e analysis to take more time. If it does t take more time, the extra informa-n in it must be flowing in parallel her than in increased depth.

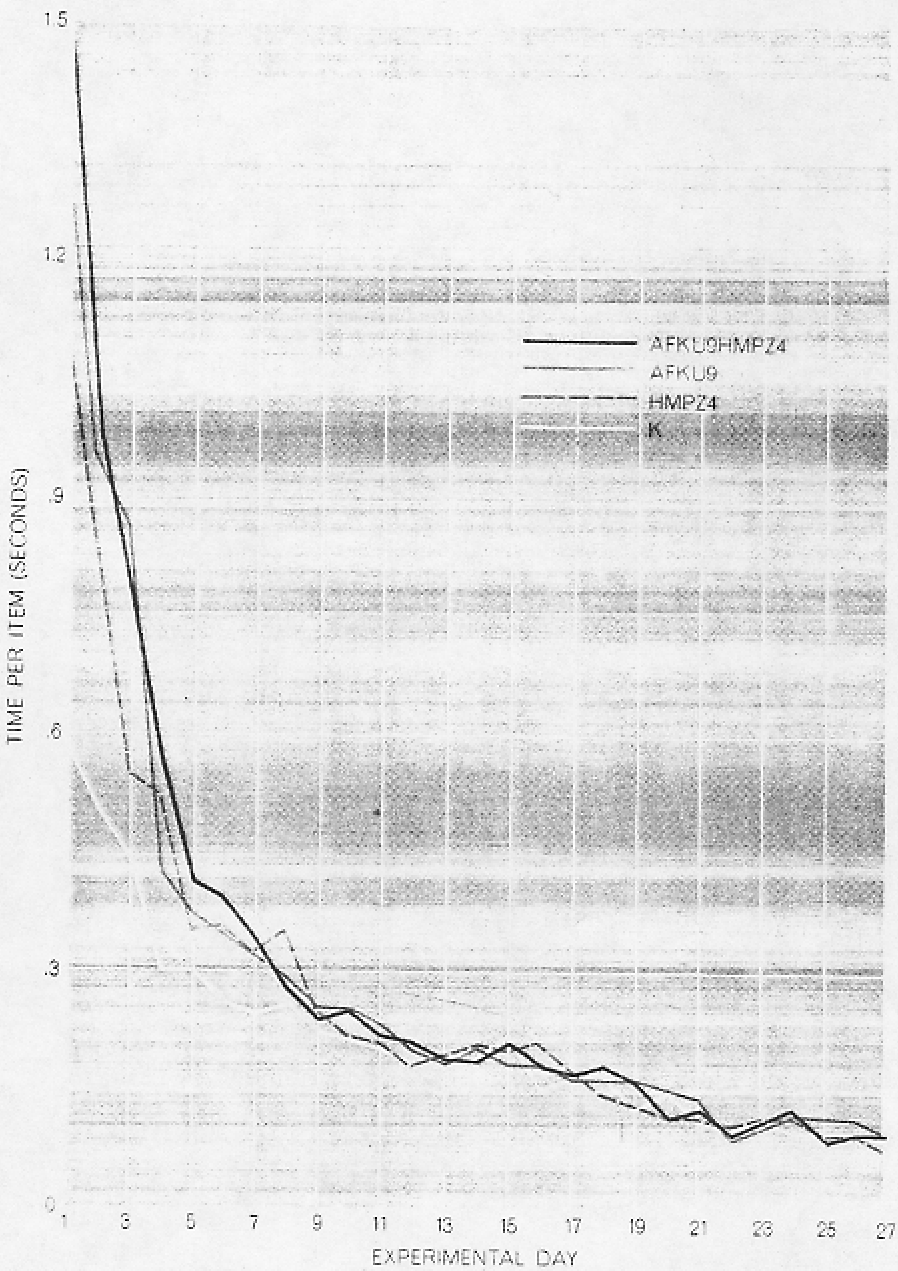
There was still a possibility, of course, that the fourfold scan is indeed slow-than the single ones, but only by an ount too small for detection by our thods. One way to investigate this ssibility was to add more targets to e search. We therefore decided to find e if our subjects could look for 10 gets as quickly as for one. We had additional theoretical reason for lving such a broad search. It is well own that most people cannot hold re than about seven items in their mediate memory, and also that they ally fail at certain tasks involving gment if there are more than about en categories [see "Information and mory," by George A. Miller; SCIEN-C AMERICAN, August, 1956]. These s are all rather complex, however, we wanted to see whether or not milar limitation would apply to nning.

n the 10-target experiment we did t delay the introduction of the com-x conditions until the subjects had tered the simple ones. From the out-they worked on four kinds of search. ugh only one kind of search was ucted on a given list, all four kinds to be done during every experi-al session. The four tasks were to h for a K; to search for one of the haracters A, F, K, U or 9; to search H, M, P, Z or 4; to search for any of the 10 letters and numbers defined in the other conditions. To find out what unpracticed subjects are up against in the 10-target condition, the reader can scan the list at the left in the illustration on the opposite page.

Understandably the subjects began by scanning much more quickly in the single-target condition than in the others. Practice, however, brought particularly rapid improvement in the ability to search for multiple targets. After about two weeks our volunteers were scanning with equal speed under all conditions, and they continued to do so until the end of the experiment. The convergence of their performance records is shown in the illustration below. At the end of the experiment everyone was scanning lists at the rate of about 10 lines a second.

On the last two days the set of irrelevant letters from which the lists were generated was changed somewhat: three new letters sometimes appeared in the context. The change was not even noticed by the subjects and it made no difference in their scanning efficiency. This provides additional evidence that a searcher does not identify the irrelevant letters as he scans a list.

These data leave little doubt that visual search can involve a multiplicity of processes carried out together. At first thought such a finding seems surpris-




**MULTIPLE TARGETS could, with practice, be found just as quickly as a single target. The experiment charted here had four conditions, requiring searches for one, five or 10 targets at once. Each point plotted here is the mean time per item for six volunteers.**

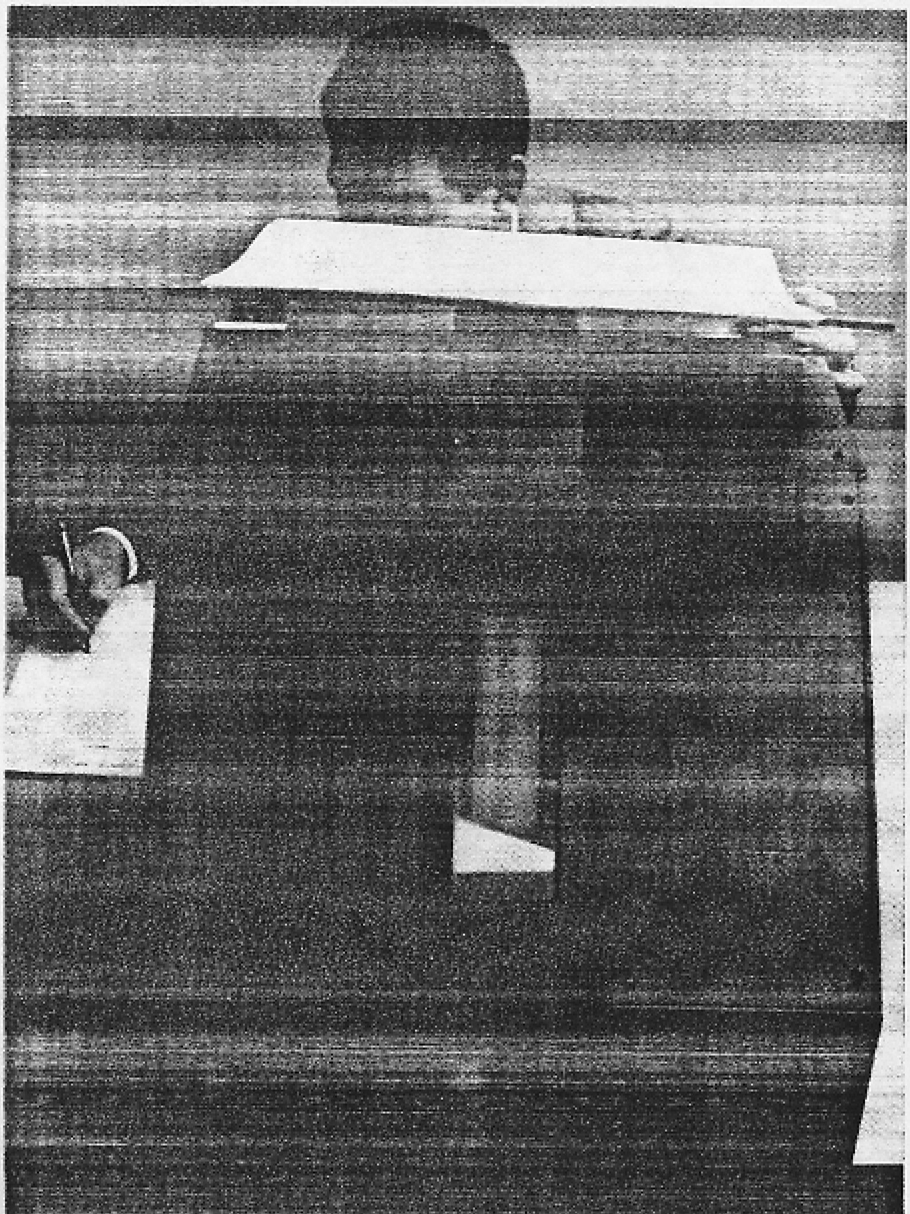
ing. Everyone is familiar with the confusion that results from trying to think about two things at the same time or from following two conversations. Indeed, a well-established body of research confirms the everyday experience that several tasks cannot be carried out at the same time without loss of efficiency. The apparent contradiction between these results and our own can be resolved by considering the relatively low level of the cognitive analysis involved in scanning; restrictions that apply to complex decision processes may not be effective for elementary visual operations.

From another point of view the simultaneity of simple visual processes is not at all surprising. Work with electronic information-handling systems has already suggested that parallel systems are preferable to serial ones for a wide class of problems. Investigation of mechanical pattern recognition, and especially the programing of computers to identify printed or handwritten letters, has shown that parallel organi[illegible] tion is particularly effective in tasks [illegible] which the defining criteria are initi[illegible] vague and must be "learned" [see "Pa[illegible] tern Recognition by Machine," by O[illegible] ver G. Selfridge and Ulric Neisser; Sc[illegible] ENTIFIC AMERICAN, August, 1960].

Our experiments have not been con[illegible] fined to searches for isolated letters. A much more interesting task confron[illegible] a subject who must search through [illegible] of words. As long as the target is a sin[illegible] gle word, however, he can treat [illegible] almost like a letter search. He [illegible] only look at the initial letters or at [illegible] other clearly distinguishing features [illegible] each word to see if they match th[illegible] the target; only when they do is further processing necessary. Indeed, scanning is extremely rapid in such situation[illegible] Even when the target is any [illegible] some familiar set of words (for exam[illegible] ple all the states in the U.S. [illegible] six or fewer letters), subjects can sc[illegible] very quickly, employing what [illegible] be letter-searching techniques.

To ensure that the items on the l[illegible] were dealt with as words, we found that we had to define the target in terms of meaning. For instance, we would [illegible] a subject to search through lists such as the one at the right in the illustration on page 98 to find "an animal" or "a man's or woman's first name." Such a search has many targets indeed. There are hundreds of animal names and first names, even if word length is restricted to six letters or fewer. In the case of word-hunting we still do not understand the processes involved well enough to characterize them as "simultaneous" or "successive"; our research was directed toward answering some preliminary empirical questions. We wondered how fast such a scan can be carried out, whether or not the speed depends on the number of potential targets and to what extent the subjects must "read" the irrelevant words through which they search.

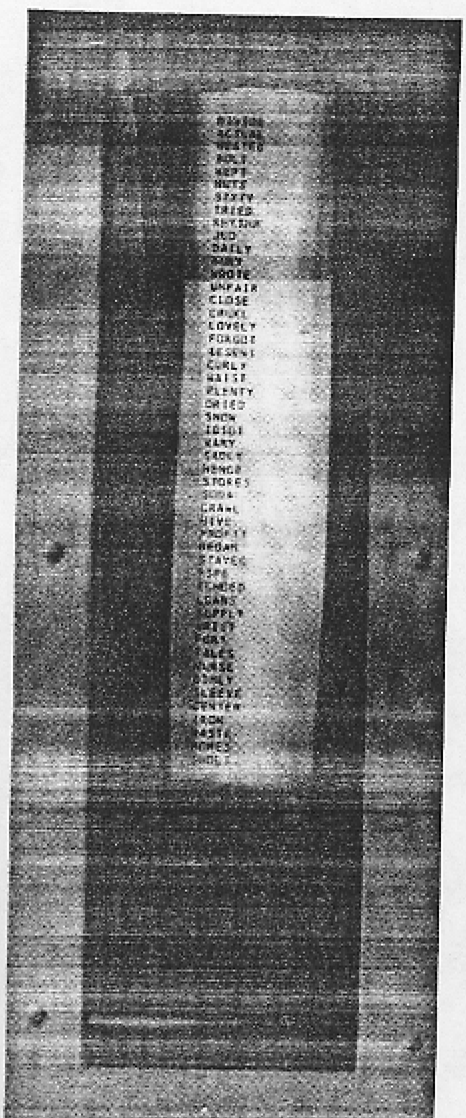
The irrelevant words in our lists were randomly generated from a pool of about 8,000 English words three to six letters long, checked to eliminate animal names, proper names and [illegible] words. In these lists we embedded [illegible] ther animal target names selected from a pool of about 115 animal names [illegible] proper names chosen from among [illegible] fairly common first names. (None of [illegible] subjects, of course, would be likely to "know" precisely these pools of [illegible] sible targets, but they were drawn from the well-established [illegible]



**SUBJECT** (*foreground*) **sits at a viewing box in which the experimenter inserts lists. The subject turns a switch to illuminate a list and at the same time start a timer. On finding the target the subject stops the clock and the experimenter records the duration of search.**

word lists and their numbers reflect the complexity of the mental operations required for either of these searches.)

An inexperienced person can scan through a word list containing animal names more rapidly than he can scan a letter list in search of *K*, but the name-directed search does not benefit as much from sustained practice as the letter search does. By about the 15th session most people are able to scan for first names or animal names at a rate of five or six words per second; thereafter they seem to improve very little. They search as rapidly for first names as for animal names even though there are many more of the former. We also studied a condition in which the target might be, unpredictably, either a first name or an animal name; a few people are as quick at looking for either a first name or an animal name as for one of these alone; the others perform somewhat more slowly in the combined search.



**FIRST NAME OR ANIMAL** is the target in this list. "Jud" is found in the 10th line.

How shall we conceptualize an information-processing system that decides in a fifth of a second whether or not a given string of letters stands for an animal? Does the subject make decisions about the meanings of the irrelevant words he scans? Can we assume that he "reads" each word? Note that the scanning task is both more and less demanding than ordinary reading: more because the scanner must examine every individual word, less because he need not establish connections between words. The scanning rate of five words per second, or 300 words per minute, is not particularly rapid compared with the reading speed of many college students.

The words are certainly not being read subvocally; the same subjects go only half as fast when they are asked to read the lists aloud as quickly as possible. Most of them maintain that they do not "read" the individual words at all, even to themselves, as they scan. And the words are not examined closely enough to be remembered. When tested immediately after a scan, subjects usually cannot distinguish words that appeared on the list from words that did not.

It seems, then, that the word "read" is as ambiguous as "see" is; reading too may occur in varying degrees of depth. This conclusion is not a novel one, since everyone is familiar with the differences among skimming, rapid reading, intensive study and so on. Our results suggest, however, that varying degrees of comprehension are possible even for individual words. The subjects do not "skim" the lists by reading only some of the words. Rather, they process each word—but only lightly. Just as one can decide that there is no *K* in a given line without actually identifying the letters, so too one can determine that a given word is not an animal name without firmly deciding what it does mean. Whatever may be the processes by which this is done, our data indicate that they do not involve seriatim comparison of the word with all possible animals; if they did, first-name searches would be much slower than animal-name searches. On the other hand, the processes are slower, and presumably more complex, than those needed for finding individual letters.

By laboratory standards our subjects are well trained and have acquired an unusual skill. It is quite certain, however, that we have not approached the limits of human capacity for rapid [illegible] plex, multiple searching. The [illegible] ments of our subjects are modest [illegible] compared with the daily work of [illegible] ple who are accustomed to looking [illegible] several thousand targets at [illegible] readers in any newspaper-clipping [illegible] cy. Such a firm may have [illegible] clients, each of whom wants a [illegible] of at least any newspaper story [illegible] he or his firm is mentioned; [illegible] many clients will be interested [illegible] appreciable number of different [illegible] names and titles and others will [illegible] their clipping needs in a [illegible] eral way. For example, a peace [illegible] may ask for every reference to [illegible] ment, arms control and the like, [illegible] as a manufacturer of burglar [illegible] may want to have the name of [illegible] local victim of theft or robbery. [illegible] over, the agency's client list is not [illegible] 10 or 20 new clients may engage [illegible] services every week and a [illegible] number may discontinue. It takes [illegible] or more to train a clipping [illegible] scan newspaper type at well over [illegible] words a minute, keeping watch [illegible] the agency's targets. Error [illegible] said to be in the neighborhood [illegible] per cent for the best readers, and [illegible] ther the error rate nor the speed [illegible] to change as an agency [illegible] quires more clients.

The achievements of clipping [illegible] suggest that our own basic [illegible] is no artifact: the speed of a [illegible] independent of the number of [illegible] targets that can terminate it [illegible] fully. This conclusion applies [illegible] to the simple search for [illegible] ters and the more difficult, slower [illegible] for particular kinds of words. [illegible] likelihood it applies to other [illegible] also. The rate at which [illegible] crowd for a familiar face [illegible] not depend on the number [illegible] with whom one is familiar.

In a simple task such as the [illegible] any one of 10 letters, these [illegible] fully compatible with the [illegible] multilevel perceptual system. [illegible] gest, moreover, that a number [illegible] tions at a given level are [illegible] simultaneously. We do not yet [illegible] stand the search for [illegible] words well enough to make [illegible] the processes involved. It is [illegible] clear, however, that the [illegible] ations involved add up to [illegible] more than simply a search [illegible] nent letters and something [illegible] full appreciation of the [illegible] word encountered.