Physically handicapped people, unable to hold a telephone handset or dial a conventional phone, may soon place and answer calls with this voice-controlled telephone. Voice commands, timed with a continuously running display of lights, control the phone's operation.

Experimental Telephone Lets Disabled "Dial" by Voice

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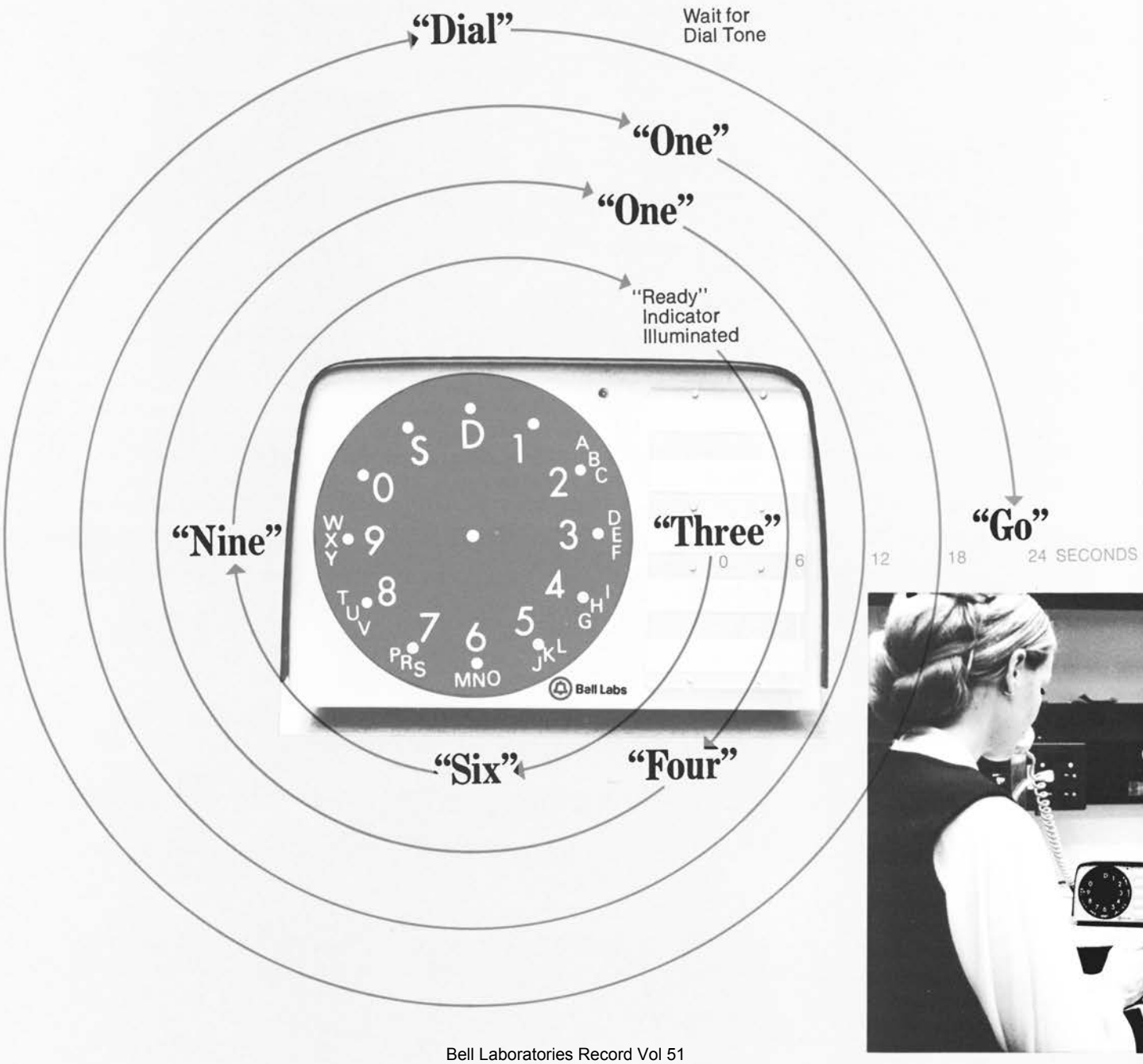

BELL LABORATORIES ENGINEERS have designed and built a new experimental telephone that handicapped people can "dial" by voice command. In fact, the user's voice controls all the operations of the phone, from dialing and answering to hanging up. The experimental telephone is a small rectangular set with a "dial" that looks like the face of a clock, having neither the rotary mechanism nor the pushbuttons common to ordinary telephones (see the photo, opposite). Each lamp near a digit or control code on this dial lights briefly in turn, and a caller operates the telephone simply by speaking or making a short sound when the appropriate lamp lights. The digits were deliberately positioned as on a clock to make them easy to locate. In addition to providing standard telephone service, the unit automatically stores the last number dialed and up to four additional phone numbers; it also allows voice-controlled operation of one or two appliances (for example, a table lamp and a television set) by operating relays connected to the appliances.

To meet the needs of individual users, the phone can be operated with various transmitters and receivers—a handset, a lightweight headset, or a small loudspeaker, for example—which connect through a jack in the back of the phone. The handset can be held stationary and supported by a device such as a gooseneck arm (a semiflexible support rod) clamped to a desk or table, so that handicapped people never need to use their fingers, hands, or arms to call.

The telephone will respond to any sound—even whistling, blowing, or tapping—above a certain threshold. This threshold is variable—a user with a soft voice may need an unusually low threshold, whereas a user in a noisy location may wish a high threshold to block extraneous noises. To lessen even further the chance of such sounds accidentally triggering digits and initiating a call, the user must turn on the phone's circuitry by entering an access code before entering the phone number. We selected the sequence 3, 6, 9 for the access code because this sequence is easy to remember and use, yet is unlikely to be entered by conversational sounds or background noises. The corresponding digits on the dial are illuminated (along with the letter D, for "dial") so that they can be identified in the dark. When the user has entered the code, a red light at the upper right-hand corner of the dial face turns on, indicating that the circuits are ready to receive a telephone number. Next the caller enters the digits of the phone number. To verify the entry of each digit, another indicator—in the center of the dial—momentarily lights. After a slight pause, the sequential lighting of the dial display continues. If the user makes a mistake or for any other reason wants to interrupt the procedure, he issues voice commands on displays S and D to shut off the unit before it seizes a line to the central office.

When the phone has registered the entire number, the user calls for dial tone by saying a short word, such as "dial," when the lamp at the letter D lights (at 12 o'clock). Once dial tone has been received, the telephone is ready to transmit the dial pulses to the central office. To activate the dial-pulsing circuitry, the caller gives a voice command—for example, "go"—during the display of any digit (but not when S or D is lighted). Now the telephone dials automatically at a standard dial-pulsing rate. During the dialing, the caller can verify the number dialed by watching the display of lights. Each lamp lights in numerical sequence, starting with 1 and stopping at the digit transmitted. For example, if one digit in the phone number was a 5, the lamps adjacent to digits 1 through 5 would each light momentarily. In addition to providing access to the circuitry, the 3, 6, 9 code is also used to "hang up" after a completed call and to answer calls.

A simple example of a dialing sequence is that used in calling the operator. The sequence of voice commands is 3, 6, 9, 0, D, and "go" (on any digit). This telephone number is the shortest and easiest to call—as it should be, in case of emergency. (Other examples are given in "Dialing by Voice," page 277.)

The experimental voice-controlled telephone (opposite) responds to any sound above a threshold level so that people who cannot move their fingers or hands are able to make and receive phone calls. The lamps next to the digits on the clocklike dial light in sequence to indicate when the unit is ready to accept a particular command. If, for example, a user wishes to call Directory Assistance, the complete series of commands, as shown opposite, is "three, six, nine" (the access code), "four, one, one" (the number being called), "dial" (the request for dial tone), "go." The user says "three" when the lamp near the digit 3 lights, "six" when the lamp near 6 lights, and so on. The lamp located outside the circular face, near the digit 2, lights after the access code is entered to show that the circuitry is ready to accept the number to be dialed. Once the user receives dial tone, he may speak the final command, "go," when a lamp lights near any digit, and the phone automatically dials.

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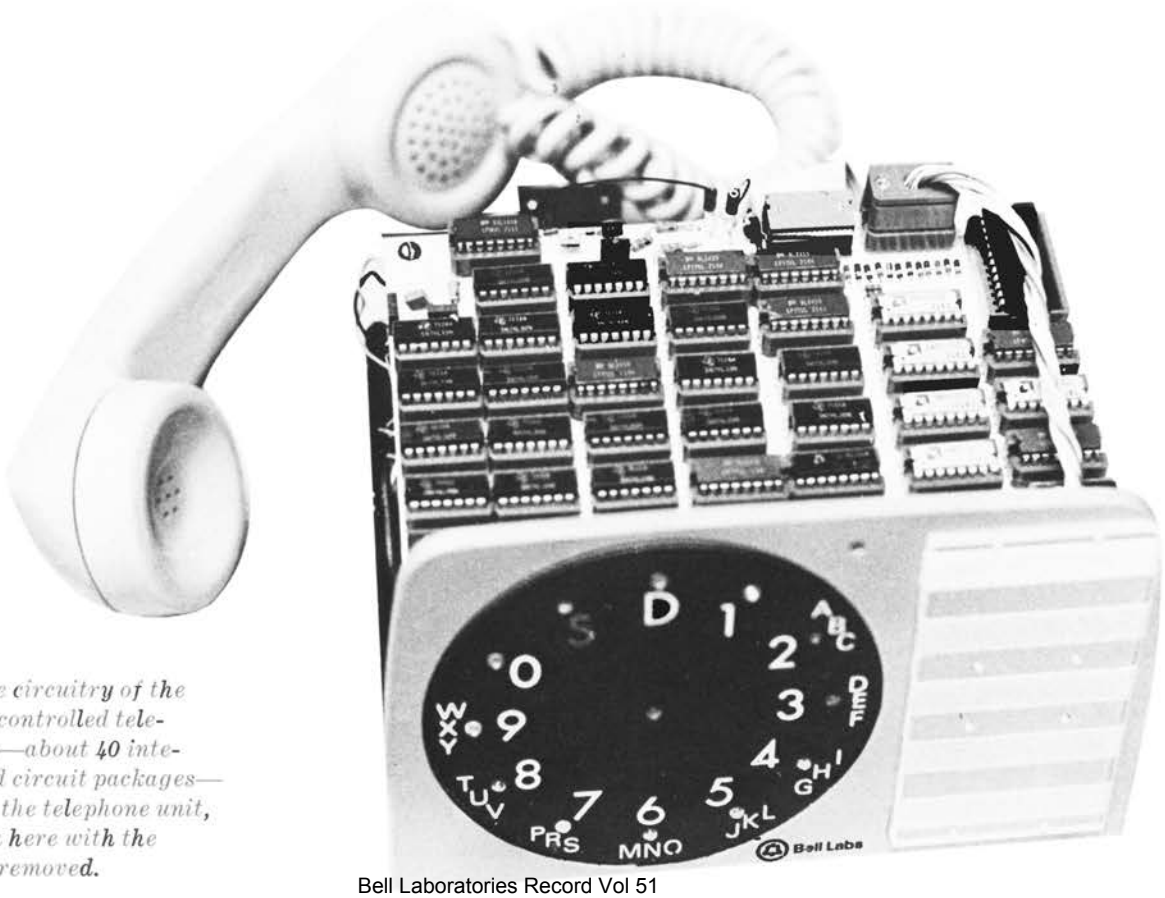
Note that the circuitry does not transmit the digits to the central office as the caller enters them. The major advantage of delaying transmission is that it avoids the possibility of the central office losing the connection if a user takes a long time to enter successive digits. In addition, by giving the user an opportunity to recheck the dialed number, this method minimizes the number of wrong numbers connected. (Further information about the functioning of the telephone appears in "How Voice Control Works," opposite.)

In determining the speed of the dial display (the time each lamp is lit), we allowed for variations in users' abilities and experience with the new set. Human-factors studies indicated that the rotational rate of the display should not be greater than about one rotation every six seconds, and we assumed that most users would want considerably slower speeds at first. We chose, therefore, to make the speed controllable via a knob on the back of the unit.

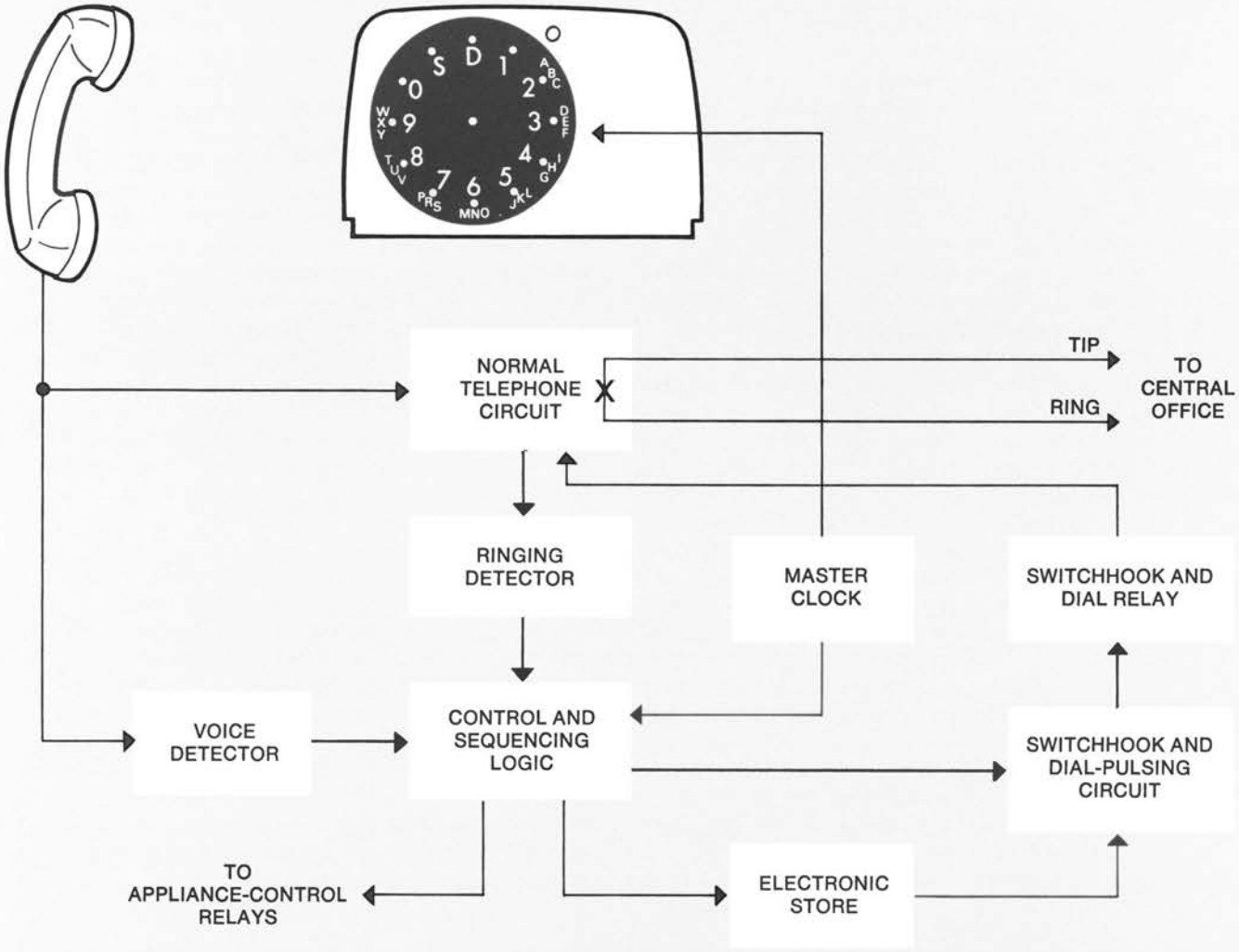
The number of digits in the access code, of course, influences the total time needed to place a call. We decided on three digits as a compromise—more would serve as an extra precaution against random sounds inadvertently turning on the telephone, but the penalty would be a longer calling time. In a recent trial, handicapped people were able to enter a seven-digit number, plus the necessary control codes, in 35 to 45 seconds. The extra time is not a severe penalty, since some people—without disabilities—take as long as 20 seconds to dial a seven-digit number on a rotary dial.

The user will not always need to enter the complete number anyway because there are abbreviated codes for calling stored numbers. The code for the last number dialed, for example, is a shortcut for redialing when the number called was busy or there was no answer. Since we planned to provide a store location for this number, we decided to include four additional locations so that the phone could be used as a repertory dialer. Any number of up to 16 digits can be stored in these locations by voice command (see example on page 277). It is also easy to substitute new numbers for old ones when necessary. Labels can be attached to the phone to remind the user of stored numbers.

Handicapped people who retain some movement of finger, foot, knee, or head may prefer to control their telephones by switch rather than by voice. Any one of several kinds of switches—a foot switch, a miniature snap-action switch, or even a breath-controlled switch—can be connected through the back of the unit, thus disabling the voice-control mechanism. Such switches are particularly valuable for use with a speakerphone or in any location with noise levels loud enough to interfere with voice-controlled operation.



All the circuitry of the voice-controlled telephone—about 40 integrated circuit packages—fits in the telephone unit, shown here with the cover removed.



How Voice Control Works

The voice-controlled telephone is activated by any short sound that meets two requirements: (1) it occurs simultaneously with the display of a digit and (2) it is loud enough to exceed the threshold of the set's voice detector (left). When these two requirements are met, the displayed digit enters an electronic store (bottom center) as part of the called telephone number.

To assure that numbers are not stored accidentally because of random sounds, the telephone does not accept numbers unless the control and sequencing logic (center) first detects an access code consisting of the digits 3, 6, and 9 entered sequentially. Thereafter, each digit is stored in the order entered. When the electronic store contains the complete telephone number, the user waits for the display letter "D" to light and enters a command, such as "dial." This action causes the control logic to close the switchhook and dial relay (right), allowing the dial tone to be transmitted from the central office over the telephone line (tip and ring leads, upper right). During the display of any succeeding digit (but not S or D), the user issues the final command (such as "go"). When this happens, the control logic directs the electronic store to transmit the telephone number (which is stored in binary code) to the switchhook and dial-pulsing circuit (lower right). This circuit converts the digits into dial pulses and transmits them to the central office, where the appropriate connection is made. The control logic also directs the display of dial lights that allows a user to verify the number dialed.

For incoming calls, the ringing signal is fed into the ringing detector (center), which directs the signal to the control logic. To answer a call, the user must enter the 3, 6, 9 code so that the control logic will respond and operate the switchhook relay. When the relay operates, the telephone goes off-hook—just as if the user had lifted the handset—allowing the parties to talk.

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Ordinarily, the new voice-controlled telephone operates on current from a transformer-rectifier unit that plugs into any 110-volt ac outlet. But since this phone may be a handicapped person's only means of communication, it must continue to operate during a power failure. We therefore included a 5-volt rechargeable battery to assure emergency operation. The battery's four nickel-cadmium cells charge continuously as long as there is house current. Should commercial power stop for any reason, the telephone will operate on battery power for several hours.

This complex but economical voice-controlled phone is unquestionably a product of integrated circuit technology. The circuitry in the experimental model consists of about forty standard integrated circuits in dual in-line packages, plus a few discrete components. All the circuitry (except for the transformer) fits within the telephone unit, which is only slightly larger than a conventional phone. To illuminate the display of each digit and control position, we used light-emitting diodes (see *Crystal Lamps Are Lighting Up the Bell System*, RECORD, *November 1972*). These miniature devices consume less power than incandescent bulbs, are inexpensive, have a long life, and are compatible with integrated circuits. A few years ago a voice-controlled telephone would have been bulky and costly, but the use of new technologies has made it possible to achieve both small size and reasonable cost.

We have investigated other methods of voice control, but none seems to offer the simplicity and economy of this unit. Speech recognition, for example, requires circuits that can correctly interpret and dial a number spoken into a telephone receiver. This method is simple for the user, but it is currently very costly and, in addition, not sufficiently reliable.

Although some people have difficulty when they first attempt to use a voice-controlled telephone, a field experiment conducted last year indicated that most of our trial subjects were pleased with our phone and all were enthusiastic about the auxiliary controls (see "What the Users Say," below). One fact is evident: disabled persons depend on the telephone for communication, and the experimental unit we built helped them not only to make calls but also to be more independent. A handicapped person could conceivably use this phone in income-producing activities, such as providing an answering service.

Since this telephone is only in the experimental stage, service is not yet available. But we are continuing our efforts to simplify the unit and, consequently, to lower its cost. At the same time, researchers at Bell Labs and AT&T are trying to determine the number of people who would benefit from using this phone. This estimate will form a basis for deciding whether the phone should be offered to the public. If demand is sufficient, the phone should prove to be an extremely useful and economical instrument for Operating Companies to offer to their handicapped customers.

What the Users Say

To a great extent, the progress made with the voice-controlled telephone stems from the experiences of our trial subjects, who used our experimental unit in their homes and offices, at the New York Institute of Rehabilitation Medicine in New York City, and at the Kessler Institute for Rehabilitation in West Orange, New Jersey. Our subjects were all people who, because of various physical problems (multiple sclerosis, muscular dystrophy, poliomyelitis, quadriplegia, etc.), find it extremely difficult or even impossible to dial a conventional telephone unassisted. During the experiment, which lasted six months, we modified the telephone to provide as much convenience to the users as possible.

Comments were generally favorable, and people had little difficulty using the phone after they became accustomed to its operation. One patient at a rehabilitation

Dialing by Voice

The following are typical dial-by-voice sequences. Although we have used specific words in the examples, any sound above the threshold level will register.

- **To call 555-1212:**
  3, 6, 9 (turns circuitry on),
  5, 5, 5, 1, 2, 1, 2, D (wait for dial tone),
  GO.

- **To call the last number dialed:**
  3, 6, 9, D, 1 (store location for the last number dialed),
  (wait for dial tone),
  GO.

- **To store the number 555-1234 in the repertory:**
  3, 6, 9, S (for "store"),
  2 (3, 4, or 5—the repertory locations),
  5, 5, 5, 1, 2, 3, 4, S, D (turns circuitry off).

- **To call numbers in the repertory:**
  3, 6, 9, D, 2 (3, 4, or 5),
  (wait for dial tone),
  GO.

- **To operate an appliance:**
  1, 4, 7 or 2, 5, 8 (the same code turns the appliance on and off).

center, clearly elated with the phone, called it "tremendous." "My problem," she continued, "is that I have no use at all of my arms and hands. Two things that I do have are good eyesight and speech, so I feel it's just about the best thing I could have."

In another case, the telephone sometimes accidentally turned on when patients at the rehabilitation center were watching a baseball game on television. "In a room such as this," explained Rich, "you've got four guys and you're bound to have a lot of noise. When you have a baseball game on, you're going to have a lot of handclapping and it registers." Such cases occurred infrequently, however, because the timing of incidental noises is unlikely to coincide with the timing of the access code.

We asked another person, who uses a telephone for business, if he would prefer a device similar to the new unit but requiring an operator to dial. He replied that depending on an operator is inconvenient because, for each call, he must explain why he can't dial, as well as tell the operator both the called and the calling number.

"People had gotten to the point where they wouldn't call," said Pauline, who used the telephone in her home, "because they knew I couldn't pick up the phone. But with this phone, when a call does come, it's nice that I can answer it." Pauline said her one problem with the phone was that she sometimes spoke too slowly when dialing and would have to start again.

For Marie, who is a polio victim confined to an iron lung in her home, the auxiliary controls on her voice-controlled telephone were especially helpful. The two controls operated a television set and a lamp. In addition, Marie would have liked controls for her radio, her window drapes, and a sliding door.

Most of the users regarded the voice-controlled telephone favorably. Some enjoyed its convenience; others found it indispensable.