SIGNALING TONE SIMULATION IN AN EMERGING COMMUNICATIONS SYSTEM IMPLICATIONS FOR TRAINING AND UTILIZATION

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SUMMARY

The implications of early simulation of emergent electronics systems are discussed. The effect of simulation on training programs and system usage in the field are illustrated by a recent experiment involving a new military communications system. Potential savings in money and time are identified, as well as increased system effectiveness as a result of early system evaluation. Early simulation is shown to significantly contribute to: (1) more cost effective training; (2) identification of problem areas within the system; (3) a realistic appraisal of system performance; (4) possible improvement of overall system effectiveness; and (5) savings in time throughout the systems life cycle.

The purpose of some aspects of training is, unfortunately, too often seen as a remedial effort to teach someone how to use a piece of equipment or a system which should not have been fielded in the first place (at least in its present form). No matter how cost effective the training process becomes, it cannot produce skilled personnel if the systems they are to work with are too complicated for anybody to ever use them effectively. As General John J. Hennessey said in Signal Magazine (March 77 issue) "Too often we discover that the success of the tactical system is the result of the extraordinary effort of our dedicated men and women overcoming, rather than being aided by, their equipment." It's a case of "if you're not part of the solution, you're part of the problem" and in order to get maximum benefit from the problem of equipment, the ideal situation would be to have a minimum amount of complex things to teach.

However, as we're all aware, it's seldom so.

Tasks in the "Age of Electronics" are becoming more intricate with each new item of equipment, and the total effect of this trend is certainly <u>not</u> likely to make training people in the future any easier. What I would like to demonstrate here is a way in which <u>early</u> simulation of new systems can be used to substantially reduce training problems and increase effectiveness of the user and the system. As an example, I will use a study in which early simulation of the signaling tones to be used in a new tri-service tactical telephone system was examined. Through electronic simulation of the "real-world" way in which this system was to be used, not only was a significantly earlier evaluation of this system possible but also potential training aids, possible problems, and their effects on user performance could be compared.

What emerged from the study were five key issues:

1. <u>Cost effective training begins in early system development</u> - in other words, system development should interact with user training and doctrine requirements to produce a system with the fewest possible training problems.

2. <u>Early simulation can identify potential areas of concern in terms of training and use</u> - the cost of early simulation can be more than recovered in terms of permitting extra lead time for designing training methods and procedures to deal with learning the system, rather than having to "patch up" an inappropriate procedure or training aid.

3. <u>Simulation + User Input = Realistic Appraisal</u> - too often the constraints of the system development process prevent an accurate assessment of the best way to show someone how to use it. Simulating use with actual military personnel allows formation of a more accurate picture of the learning process and can lead to development of a realistic method for teaching military users.

4. <u>HFE + Training = System Effectiveness</u> - if Human Factors Engineering (to provide an easily used system capable of quickly and efficiently performing its function) can be combined with proper training for the user to perform those tasks necessary to operate the system, the result will more than justify the effort involved.

5. <u>Time, the Irreplaceable Resource</u> - The most valuable resource to be saved through early simulation is time. Growth in life cycle costs increases tremendously in the later stages of system development and deployment. A minor correction on an earlier prototype (or, most effectively, on a blueprint) could result in saving truly staggering sums of money as well as considerably

increasing the value of the system to the nation's defense effort. No resource is as critical (or as expensive) as time, and if a simulation device can be used in place of an enormously expensive and sometimes not yet fielded piece of equipment to take an early look at a system, so much the better.

As an example, a new DOD communications system is being produced which uses signaling tones during a telephone call to indicate to the user the status of his call. This system has many of the familiar tones such as dial tone, ringback, and busy signal, and it also has a number of unique tones associated with various calling features such as multiple conferencing, call transfer and nonsecure warning tone. As new features were added to this system, the total number of tones that could be presented to the user during a call reached 16. As an aside, it should be added that this is not a unique example within the field of communications, but rather it is typical of current trends among many electronics manufacturers - reflecting increasing system complexity with increasing interface complexity, a consequence which need not and indeed should not follow.

In order to take an in-depth look at this system, it was necessary to construct a simulation device which could deliver the correct tones during an actual telephone call situation. Due to the astronomical cost of the digital switching system itself, as well as the logistics problems involved in tying up a system which had not yet been completely finished, simulation was an inexpensive means to provide a test vehicle for evaluation. The principal apparatus used in this study is illustrated in Figure 1.

This apparatus was built using common pooled equipment from an electronics shop which services the various directorates of our laboratory. A minimum of new construction was made, in an effort to keep costs of the final system as low as possible.

Since the new digital system will replace an existing analog set-up, it was also necessary to simulate the current analog system in order to obtain some idea of what difficulties would be encountered during the period of transition - i.e., for a considerable time, while the new systems are being fielded, subscribers may have to deal with both sets of signaling tones (analog and digital).

The signaling tones were stored on a Honeywell Model 5600B 14-channel analog data recorder, which was used in the playback mode during testing. Each participant used a TA-341 telephone set to initiate and receive simulated calls. Although the tones were presented to the participants on a self-initiated basis, the actual tones to be presented were controlled by the experimenter through the use of the Tone Controller

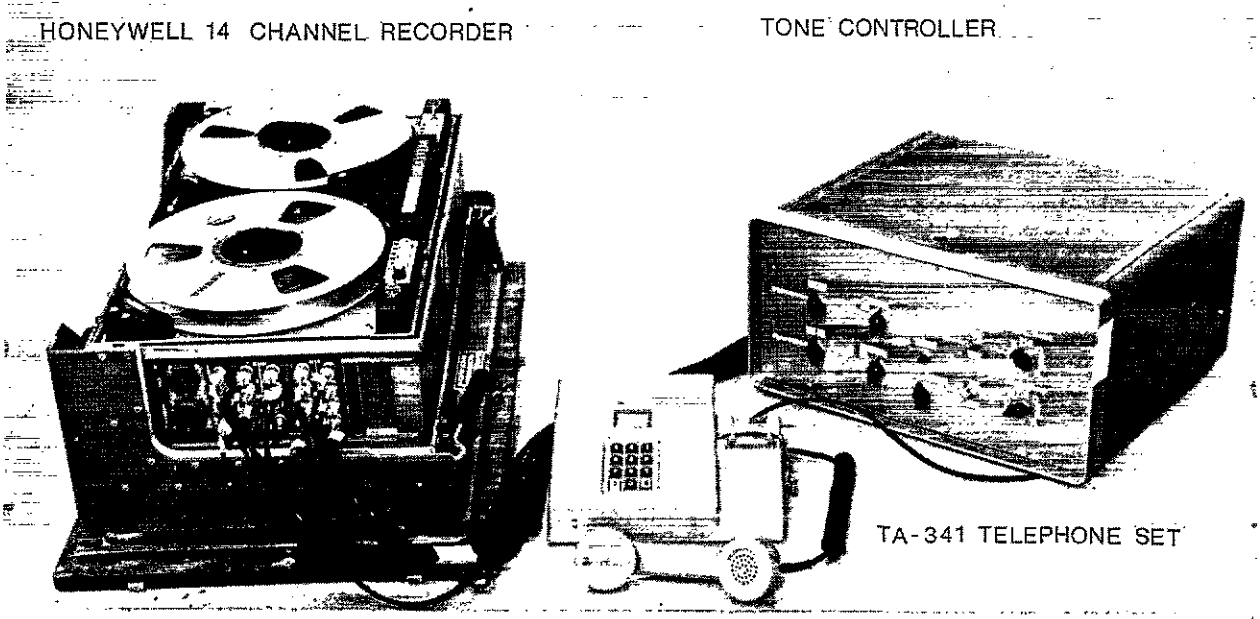

Figure 1. Principal Apparatus

(selector) 1. *For example, the participants* were told to initiate a call to telephone number 601. The experimenter would set the "hook circuit switch" to Channel No. 1 and the "key circuit switch" to Channel No. 4.

As each participant went off hook, an electronically operated switch in the Tone Selector closed the "hook circuit," which played back a continuous 425-Hz tone (dial tone) into the participants' headset receiver. The participant then keyed in the digits 601. The keying of digit "6" caused the "hook circuit" to open, cancelling the dial tone. Keying the digit "1" closed the "key circuit," which played back 570 Hz, 2 seconds on, 4 seconds off (normal ringback tone). Replacing the receiver on its cradle opened the key channel, cancelling the ringback tone.

The study was divided into two test periods (Phase I and Phase II) separated by a 30-day rest period. The general test procedure is illustrated in Figure 2.

The "basic" conditions were those which the user would encounter during a normal call. As indicated in Figures 3 and 4, these include such things as dial tone, ringback and busy signals. The "full service" conditions utilized the full capabilities of the system and included tones for such features as call transfer dial tone (situation number 18), broadcast conference notification tone (15) and others as noted.

The Phase I test period was concerned with acquisition of initial proficiency, and identification of the signaling system's problem areas. The Phase II test period was purposely scheduled after a long period where the participants received no practice and/or training related to the study. This was in order to address the question of how long the *participants would retain their proficiency.*

The two test periods were structured similarly; first testing on the two basic conditions, then on the two full-service conditions. One of the two participant groups was assigned to analog test conditions only, the other to digital test conditions only. The resulting arrangement simulated subscribers first being subjected to the basic tone situations and later, after having gained experience with the system, moving on to use the full services on the same telephone instrument (analog or digital). This test design was considered realistic for the full-service subscriber who would first familiarize himself with the basic services before attempting to use any of the more sophisticated features. The test design also allowed for isolating and evaluating how well subscribers would use the basic services.

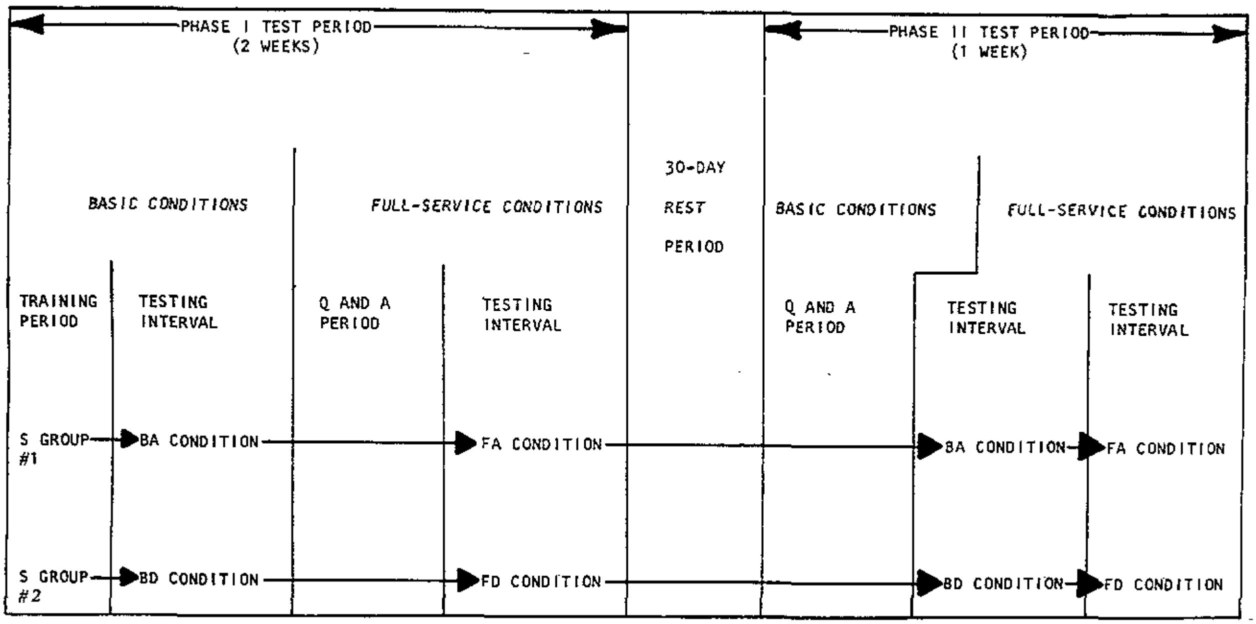

Figure 2. General test procedure

[1]For complete details on this apparatus, see: Wolfe, O. C. Apparatus for telephone tone study, HEL Technical Note 5-76, September 1976.

Twelve military personnel (five officers, seven enlisted) from the 42d Transportation Bn, Ft. Meade, MD, participated in this study. Due to the nature of the study, it was necessary that the participants have normal hearing and tone acuity. Since intelligence scores were needed for purposes of possible correlation with speed and ease of learning, each participant was given the Otis Quick-Scoring Mental Ability Test (high school, Form A). The range of IQ scores was 82 through 124 (mean IQ was 107). The participants were matched by tested IQ level and randomly assigned to either analog or digital conditions.

The procedure followed for each simulated call in the test runs was basically the same. The participants were directed to place or respond to some specific simulated call. They were given the opportunity to review the abbreviated and/or detailed written instructions on the call-processing features. During the call process, the participants would receive a signaling tone. At this point, they would choose an answer from their list of possible answers and mark it on their answer sheets. After all participants had put down their answers, the experimenter told them the best answer. This form of reinforcement was considered analogous to the "experienced-user advice" usually available to the novice subscriber. After all discussion on the "best answer" was completed, the participants would wait for further instructions from the experimenter.

Three levels of response quality were used to allow the participants to express incremental advances in learning. The three levels were defined as follows:

Level One: acceptable but less-than-satisfactory responses. At this level a correct response demonstrated that the participant knew the correct basic reaction to a tone, but had no real understanding of its meaning (e.g., hang up, but you're not sure why).

Level Two: satisfactory responses. At this level, a correct response demonstrated that the participant knew the correct tone reaction and its general meaning (hang up ... something is busy -- either the line, the trunks or the special service requested - you don't know which).

Level Three: more-than-satisfactory responses. A correct response at this level showed that the participant also understood some of the signaling-system nuances that were not crucial to subscriber effectiveness, but which were beneficial. (Hang up ... the number called (line) is busy.)

For both analog and digital conditions, participants showed a significant degradation in performance when transitioning from basic to full-service levels. IQ was highly correlated with the number of trials to reach criterion at each level; a higher score on the general intelligence test indicated that fewer trials would be needed to reach criterion. Certain tone conditions demonstrated noticeable deviation from the mean (>1) and were tentatively identified as presenting obstacles to complete mastery of the system.

As can be seen in Figures 3 and 4, the participants had difficulty with certain of the tone situations involved in each of the conditions.

As the number of tones and tone situations increased from basic to full-service, participants experienced difficulty not only in learning new tones, but also in retaining previously learned material. This inhibition to learning was greater for certain tones and tone combinations.

In Figure 4, for example, the preempt tone in the basic digital (BD) condition required 11 trials before the participants reached criterion. In the full-service digital (FD) condition, the normal time to reach a level-two response criterion for the same tone was only two trials; however, during a conference call (situation 22) it required 11 trials before the participants learned to differentiate between the preempt tone and an alternative possibility (situation 20, conferee disconnect). The preempt tone is a 1½-second burst of 440/620 Hz dual tone, while conferee disconnect consists of a 1-second burst of dual 480/620 Hz tone, only a 40 Hz difference. Conferee disconnect tone was rated as one of the three most difficult tones by 10 out of the 11 participants who completed the questionnaires at the end of Phase II testing.

Another situation of concern to the participants was the 1-second duration of the conference-notification tones. Because the tones are presented immediately as the receiver is lifted off-hook, the participants frequently noted that, unless they put the receivers to their ears while still holding down the interlock device on top of the phone and then lifted their fingers from the phone, it was very difficult to hear a sufficient amount of the tone to discern whether it was a preprogrammed--conference or broadcast-conference notification tone. Since it is unlikely that this will become standard operational procedure for answering the telephone, it is apparent that some modifications was called for in the area.

Written instructions were presented in two forms, a one-page set of brief instructions which gave only a minimal description of call processing information, and a detailed set which gave elaborated instructions combined with a narrative description of the frequency and cycling rate of the tones involved.

Of the 11 participants who completed the questionnaire, five preferred the abbreviated instructions, and six preferred the detailed instructions. The lack of clear preference, combined with the length of time required to master the full-service conditions, tends to suggest that neither version is particularly effective in transmitting the needed information. It can be anticipated that the more traditional type of written instruction, such as was used in this study, will probably be at least somewhat inadequate to the task of teaching the new subscriber how to use the system.

In general, the study served to illustrate the importance of early simulation of complex systems as a method for realistic evaluation and remediation. In terms of the key issues raised earlier:

(1) Cost effective training - early simulation of this system permitted the

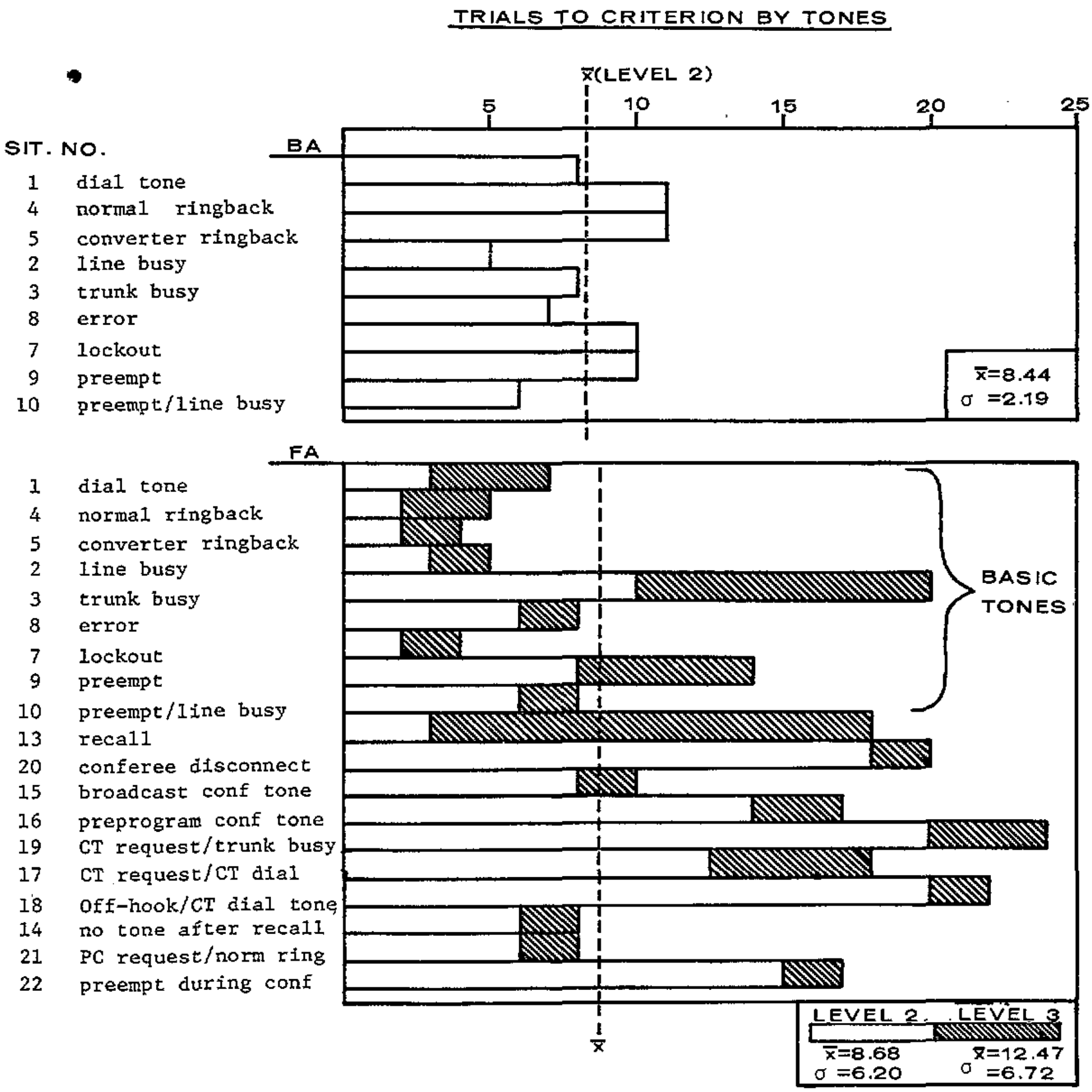

Figure 3. Trials to criterion by tones--analog conditions

development of a relatively inexpensive training device which can be modified and improved for use with this and other systems. Requests have already come in from Army training facilities for information about this device. By extending the lead-time for producing a training aid, significant increases in quality and effectiveness can be gained.

(2) Identifying potential areas of concern - problems of complexity and training methodology emerged much earlier than they would have without simulation. This will permit the expenditure of extra remediational efforts in those areas where they will do the most good. Hopefully, a combination of system "fixes," combined with development of more effective aids to learning the system (e.g., perhaps flow-charting the instructions), will result in the fielding of a system which is "part of the solution" to reducing the complexity of the military electronics environment.

(3) Realistic appraisal - use of military participants in a simulated operational exercise was essential. Too often, systems are evaluated by the engineers who built them and the government representatives who helped monitor the design and fabrication process. It's like trying to proofread a term paper

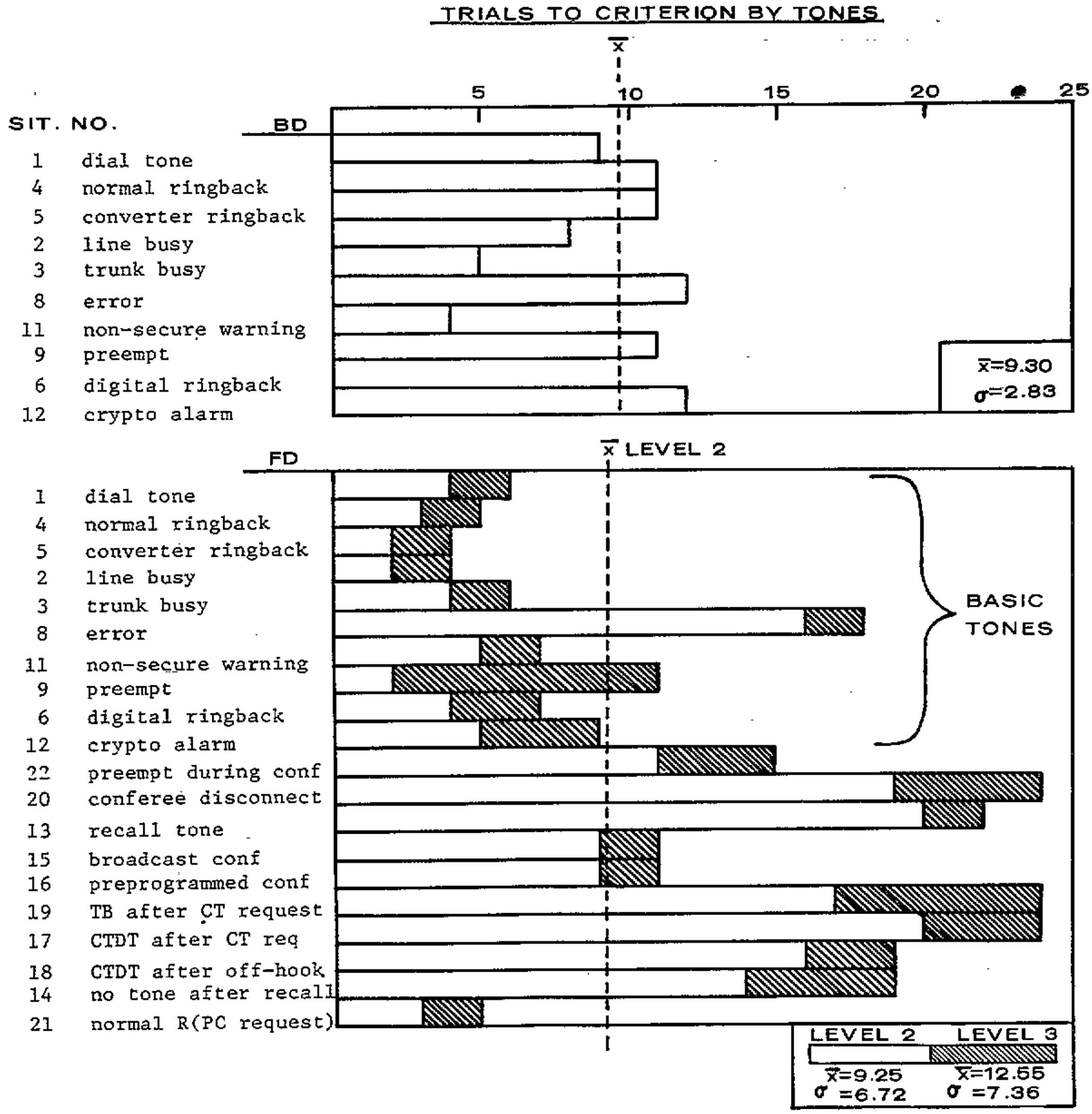

Figure 4. Trials to criterion by tones--digital conditions

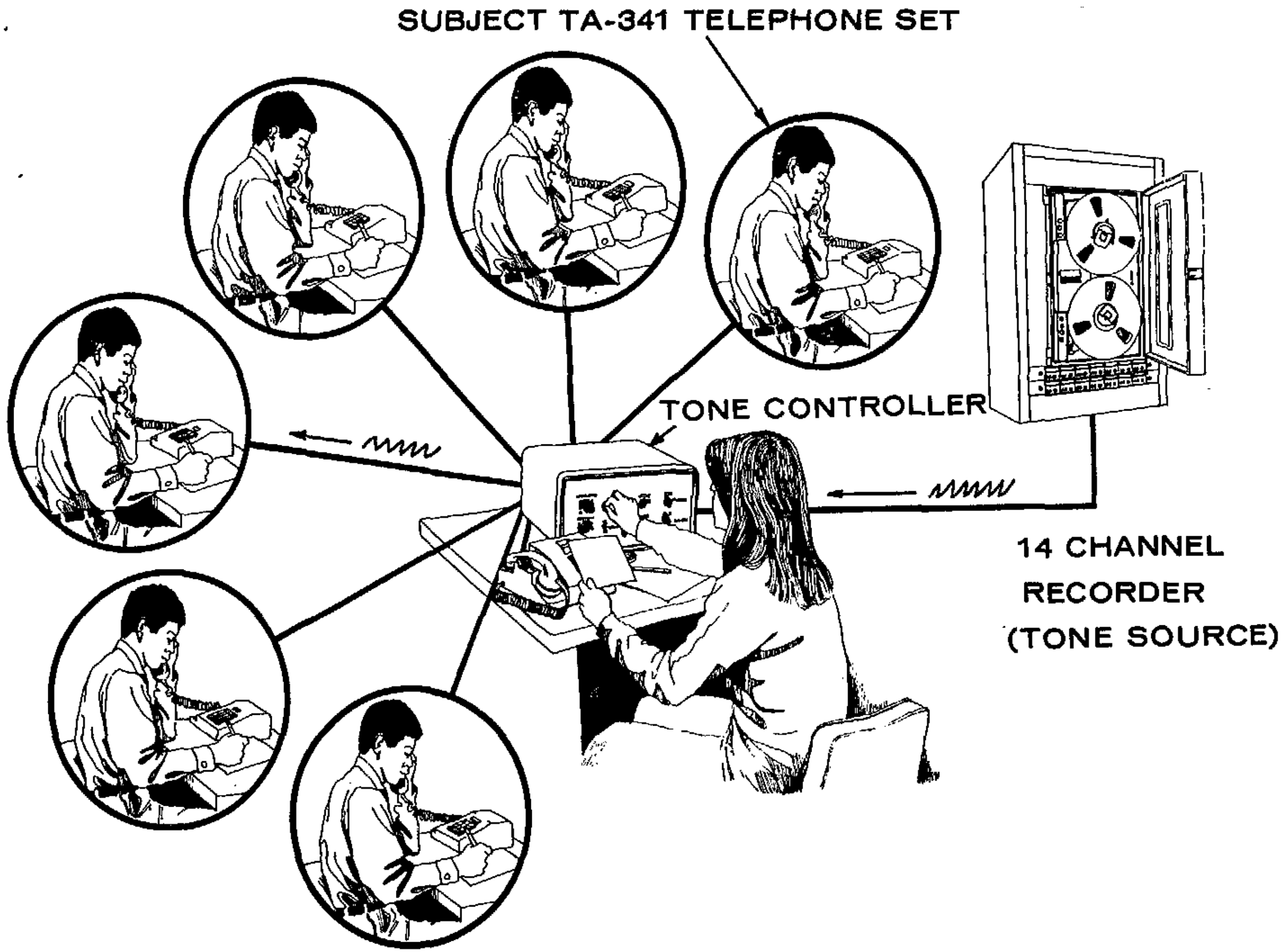

Figure 5. General apparatus arrangement

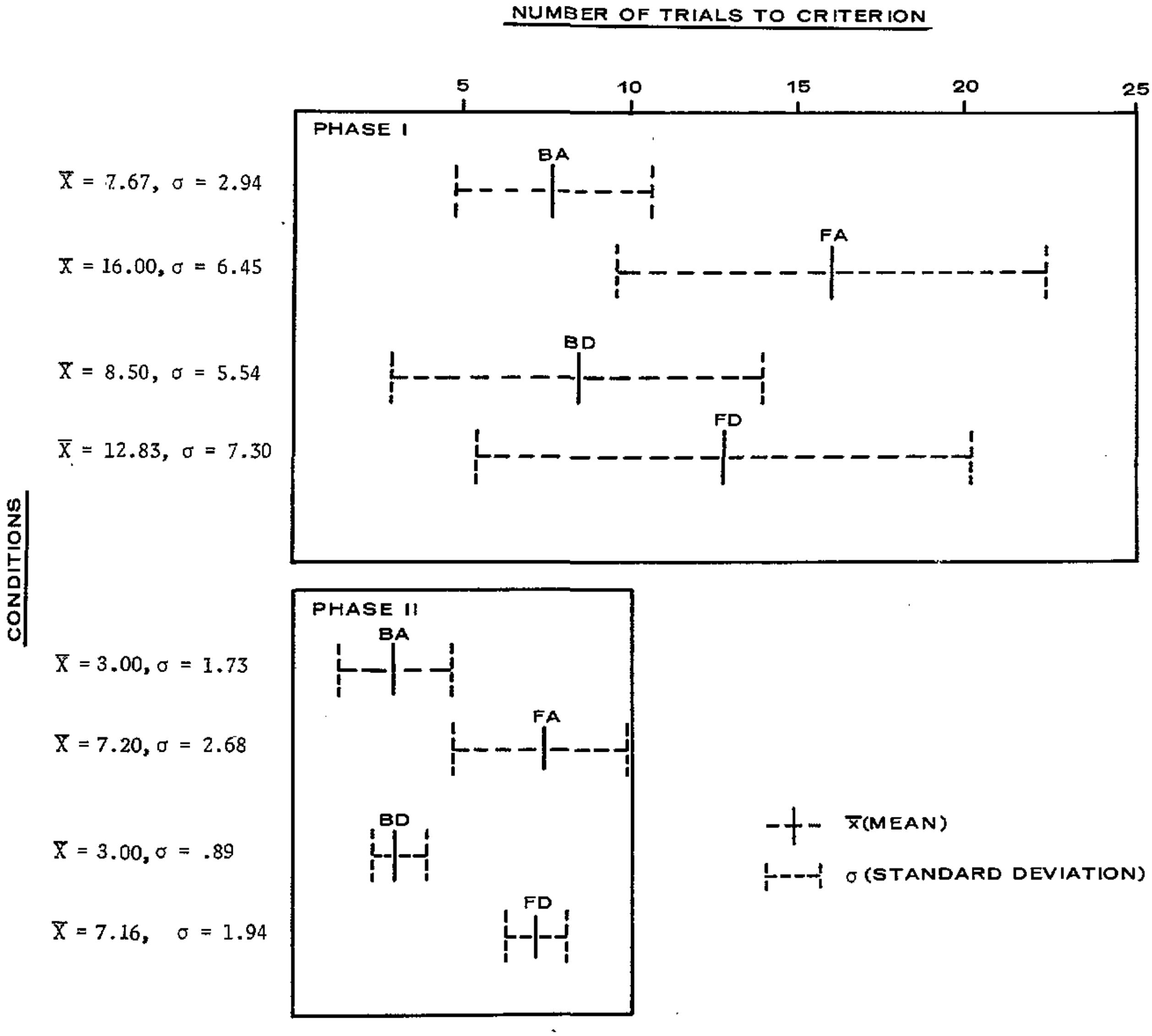

Figure 6. Trials to criterion as a function of condition and level of treatment--Phase I and II

that took months to research and write - you tend to fail to perceive what will go through the mind of the naive reader, and you frequently omit information which is well-known to you but unknown to the reader. Similarly, engineers and scientists quite often forget that the majority of eventual users of their products are interested in the device as a means to accomplish a mission, rather than an end product in itself. If you need a jeep to get through the mud, a Rolls-Royce will be of little value even if it is a much more mechanically sophisticated example of the genre.

(4) System effectiveness - early simulation of emergent systems can result in a more effective program of training and utilization. Good human factors input and development of appropriate training aids can combine to make the man-machine interface with a new system a pleasure instead of a chore. And a system that's easy to understand and use in peacetime conditions will be an absolute asset in times of conflict.

(5) Time - to be used effectively, the resource of time requires that a system and its interaction in a realistic environment with the user be examined as early as possible.

In summary, time can neither be created nor destroyed, it can only be spent productively. It is my intent in having presented this analysis to illustrate a use of simulation devices which permits the most effective "spending" of this most valuable resource. Through a combination of good human factors input during development, early simulation, and effective training procedures, maximum value will be obtained in terms of the resources expended.

Simulation can be more than a training methodology - it can be an invaluable resource in itself.

ABOUT THE AUTHOR

MR. LARRY A. PETERSON is an Engineering Psychologist employed by the Department of the Army Human Engineering Laboratory at Aberdeen Proving Ground, Maryland. His primary area of involvement is directed toward evaluation of current and proposed devices in the field of communications-electronics, and in analysis of the effects of the continually increasing complexity of these devices and systems on human performance. He is coauthor of a technical memorandum on Subscriber Effectiveness as a Function of Signaling Tones Associated with the AN/TTC-39 Circuit Switch and is currently engaged in advanced research on the problem of communication signal complexity in the military environment. He is also performing a preliminary analysis of technical control for communication networks, centering around the difficulty involved in fault detection, isolation, and correction. Mr. Peterson is a graduate of Towson State University, where he received both his B.S. and M.A. degrees in psychology, and is currently taking courses at the University of Delaware in learning and motivation.