Behavior Research Methods & Instrumentation
1980, Vol. 12 (2), 160-164

LABSIM: A data-driven simulation program for instruction in research design and statistics

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LABSIM is a general-purpose FORTRAN program that simulates the collection of data from laboratory experiments. Student-specified parameters are employed in a multiple-regression model that allows manipulation or control of up to 10 potential independent variables. Variables may be discrete (up to eight levels), continuous, or range (e.g., IQ). Raw scores may be generated for up to six groups, optionally accompanied by statistical analyses for simple between- or within-subjects designs or for factorial designs, including mixed factorial designs. Seventeen models (content areas) are currently available. As contrasted with other simulation programs, LABSIM models are exceptionally easy to design and implement; no computer expertise is required. Summary data automatically collected by LABSIM indicate a high success rate and extensive use of the program beyond course requirements. The current version of LABSIM is available in either batch or interactive form. A newer version that allows the simultaneous manipulation of up to three independent variables will be available soon.

Use of computer-based instructional systems is now common in psychology. The variety of programs in use has given instructors of research methods and statistics courses a new freedom in course design and teaching strategy. Simulation packages such as MESS (EXPER SIM) and Bewley's (1974) *Cognitive Psychology* allow the instructor to assign realistic projects (e.g., studies of pattern perception, imprinting, etc.) that were previously impractical or impossible to perform as laboratory experiments because of time, space, equipment, or even moral restrictions. Student-oriented statistical analysis packages have made possible instruction in and use of the complex designs that can flow from these simulation models. Time and energy can be diverted from the previously laborious tasks of setting up equipment, running subjects, and computing complicated statistics to be more productively applied in instruction about content: research design, statistical theory, and interpretation of results. The popularity of computer-based systems obviates discussion of their usefulness.

Probably the most widespread of all simulation programs in psychology (Castellan, Bailey, Lehman, McClelland, & Starr, 1977) is EXPER SIM. EXPER SIM clearly deserves its reputation as an outstanding and important development in computer-based instructional systems, and it appears that EXPER SIM will be with us for a long time.

As a student at the University of Michigan during the years that EXPER SIM was being implemented and class tested, I participated in the testing. Since then I have used EXPER SIM as an instructor of courses in experimental psychology in several institutions. But I have never been particularly happy with EXPER SIM for a variety of reasons.

Reprints of this paper may be obtained from Douglas Eamon, Department of Psychology, Albion College, Albion, Michigan 49224. The author gratefully acknowledges the assistance of Richard Edwards in preparing this paper and for permission to reprint Figure 1 from his implementation manual for LABSIM II. Please direct technical questions about LABSIM to Richard E. Edwards, 12715 S.E. 256th, Kent, Washington 98031.

WHY EXPER SIM DIDN'T WORK FOR ME

One problem was that the versions of EXPER SIM with which I have worked (not the most recent one distributed by CONDUIT) always seemed to produce dead rats, fired workers, and other sorts of missing data that precluded analysis of the results using the statistical programs available. While the pedagogical value of such realism is undenied, its effect was to defeat one of my primary purposes in introducing the simulations in the first place: to allow students to collect data for complex designs so as to develop their skills in constructing, analyzing, and interpreting the results of experiments we were unable to perform as individual projects. (This was a problem only for some students. In spite of my most explicit instructions, many students insisted on interpreting the "–0.0" missing data code as just another observation and added it in right along with the others, a nifty way to solve the problem of unequal Ns. These students always thought they were just luckier than the others, who inevitably had the devil's time in analyzing their results.)

Another problem was that many students found the models available to be "uninteresting," "too complicated," "too simple," or "not for me." In general, students were interested in and responsive to the possibilities of designing and analyzing their own research projects using computer simulations, but they did not respond well to the particular models available.

Further, in spite of the most complete and concise instructions, in spite of the immense flexibility of EXPER SIM to handle all kinds of misspellings and

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other entry errors, students still found the programs difficult and frustrating to run. The common complaint was that the program did not supply enough information about what the student was supposed to enter at any particular time; the input specifications were too terse.

Finally, students became quickly disillusioned with the prospect of "conducting" experiments that had been, for most important cases, already thoroughly researched in the past. My students wanted to explore hypotheses that they considered new and original, but in most cases their library research for the projects uncovered reports of studies similar or identical to the ones they had in mind. This reflects, of course, the careful construction of the EXPER SIM models, which are based on well-documented phenomena. As Stout (1974) states, "We have attached considerable importance to having models produce data that mimic genuine raw data in as many ways as possible" (p. 122). My problem was that EXPER SIM seemed to produce only data that mimicked reported research. Main (1978) seems less intent on this aspect of EXPER SIM, observing that if the content of the model is not inconsistent with the teacher's goal of teaching the strategy of research, then simplification is not a serious problem. I agree.

Clearly, some new EXPER SIM models were needed. Unfortunately, there weren't many around. Indeed, even now, CONDUIT distributes only two simulation models for EXPER SIM. Given the immense capabilities of the system (see Fuhrer, 1978, Hopkins, Fuhrer, & McNaughton, 1978), this is a surprisingly limited selection. The reasons, however, are obvious: "The model designer and programmer benefit least from the current version of the MESS system. The relative difficulty of implementing a model makes the MESS system less effective as an educational tool in two ways: by reducing the variety of models available for use, and by making it impossible for students who are not sophisticated in computer techniques to construct and explore models of their own" (Stout, 1974, p. 122).

With limited programming ability and even more limited time to write programs, using EXPER SIM left me in an uncomfortable position. I still wanted to teach the things for which I had turned to EXPER SIM, but it was difficult to do so. My experience reflects the inappropriate adoption of computer simulations in the classroom. I ended up altering my goals to fit the models available.

WHY LABSIM DID

In 1976, I attended a workshop on the uses of simulations in the teaching of psychology organized by Pete Trotter and Frank Ruggiero at the University of Iowa. The workshop focused on EXPER SIM and a new program written by Edwards (Note 1), called LABSIM.

LABSIM was then in its second version. It was originally written in PL/1 by Gerald Kissler and Richard Edwards in 1971 and was converted to FORTRAN in 1973. Although more limited than EXPER SIM in types of output (it produces only numeric data) and available only in a batch version, it included many of EXPER SIM's most desirable features and few of the undesirable ones. Far more important, however, was that new models could be constructed quickly and easily without programming skills.

As opposed to EXPER SIM, which requires the construction of a FORTRAN subroutine for each model, LABSIM models require only that the model builder specify data that describe main effects and interactions, if any, for each of the potential independent variables in the model to be built. It is in this sense a data-driven program. The data for the model are entered into a multiple-regression equation, which calculates raw data representing the dependent variable for the combination of levels of the variables in the model.

If this sounds a little complicated, it really is not. Figure 1 shows the data flow within the LABSIM system. There are three FORTRAN programs ("modules") and three data files on disk in the fully operational system. The disk data files are created by the LABSIM system itself.

In order for students to run the simulations, the instructor must first initialize the disk files containing the data for each simulation model and an optional file that monitors student simulation activity. The UPDATE module performs these functions. (UPDATE is, of course, available only to the instructor.) There are currently 17 simulation models (see Table 1) that can be entered as part of the instructor's input to UPDATE. These are card images; a complete model requires from 25 to 45 records. UPDATE uses these data to create the SIMODS file, which is accessed by the LABSIM module during a student run.

UPDATE also creates the STUDREC file, which contains records of student simulation activity. In initializing STUDREC, the instructor normally assigns a credit balance in dollars for each student for one or more models. Each student run of the model draws varying amounts against the balance, depending on the nature of the experimental design specified. The records may be retrieved at any time by the instructor, who may also add money to students' accounts and perform a variety of other monitoring functions.

The last FORTRAN module, LABSIM, is run by the student. Originally available only in a batch version, it was converted to an interactive program in 1978. Running LABSIM from a terminal causes it to request the student's "LABSIM student number" (if the gaming facilities have been enabled) and the number of the experiment (model) the student wants. Students will normally have been assigned 1 or more of the 17 possibilities and supplied a written scenario that describes the background of the problem, some suggested read-

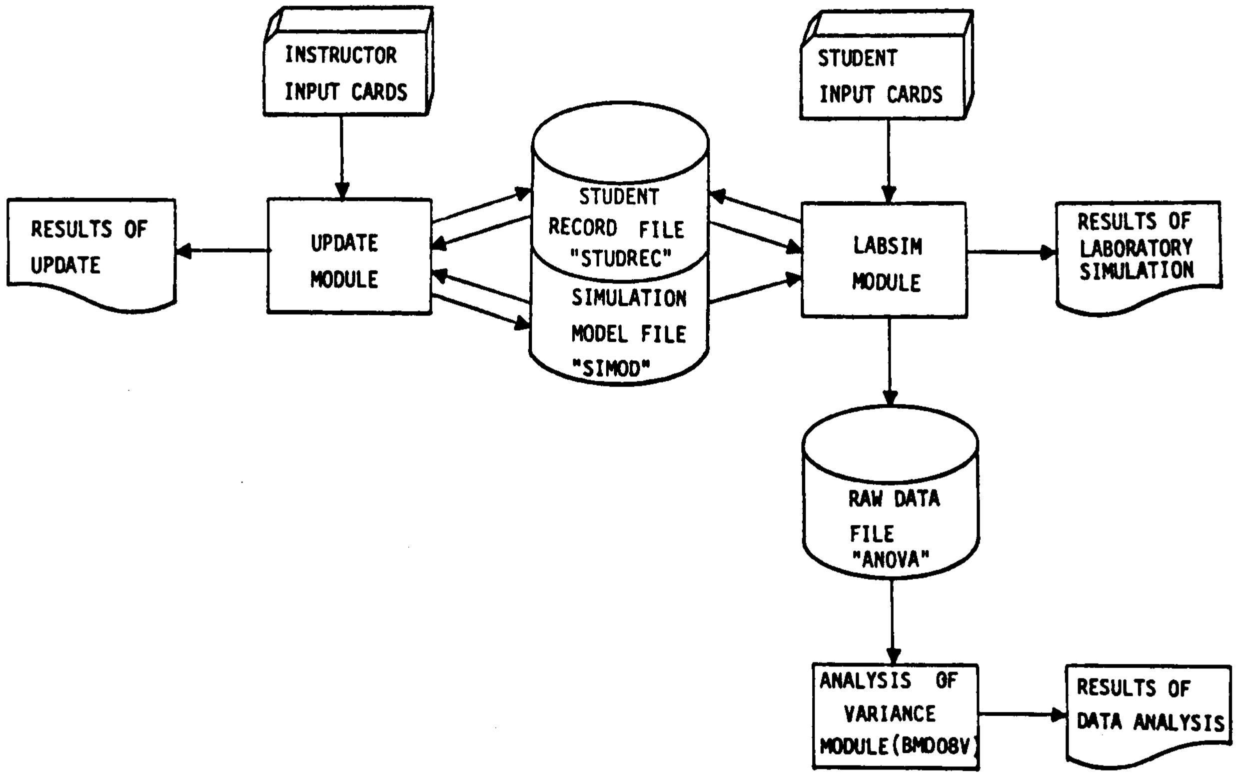

Figure 1. Data flow in LABSIM II. (Figure reprinted from Edwards, Note 1.)

Table 1
Experiment Models Currently Available in LABSIM

1. Adaptation level and judgment of line length.
2. Communication networks–Number of messages.
3. Communications networks–Job satisfaction.
4. Concept learning and concept shifts.
5. Spacing of practice in the acquisition of skill.
6. Systematic desensitization of snake phobia.
7. Effect of KCR (knowledge of correct response) on learning from programmed instruction.
8. Serial position effects.
9. Decision time for alphabetical order.
10. Effectiveness of study activities on retention.
11. Reading and comprehension of text materials.
12. Effect of adjunct questions on retention of prose.
13. The moon illusion.
14. The Stroop test.
15. The lost letter.
16. Experiments with psychic phenomena.
17. Experiments in hypnosis.

ings, and a list of the potential variables available for manipulation or control. Codes (or names) for the student-selected levels of each variable are requested for each condition in the design. In the version described here, the simulation of two-group, one-way, or factorial designs (including within-subjects or mixed designs) of up to six conditions may be specified.

These parameter values are then found in the SIMODS file, which returns effects and beta weights associated with each, and LABSIM uses these data to generate raw scores for each simulated subject in each condition according to the multiple-regression model, $DV = \beta_1 V_1 + \beta_2 V_2 + \ldots + \beta_N V_N + \beta_{N+1} V_J V_K +$ ERROR, where DV = the dependent variable score, β_I = the regression coefficient for variable I, V_I = the effect of variable I, N = the number of variables in the model, β_{N+1} = the regression coefficient for the interaction between two variables J and K, and ERROR = an error term for variance not accounted for by the variables in the model (Edwards, Note 1).

The variable names and the student-selected levels of each variable are then listed as column headings for each condition requested, followed by the raw scores for each simulated subject. All of this fits neatly and easily on one or two pages, as shown in Table 2.

At the instructor's option, the data may be written on the "ANOVA" file and treated to the appropriate statistical analysis routine.

The student must select one level of each variable for every condition in his/her experiment. This forces the student to think about the possible effect of each variable, rather than simply letting it default to a program-defined alternative. The student can, however, decide that a variable will probably not have a noticeable effect on the outcome of the experiment and leave it uncontrolled. When the gaming option is enabled, this results in saving the student money, since he/she is charged only for manipulating or controlling variables in the design. When this option is taken, LABSIM

Table 2
Output of Factorial Design for Effectiveness of Study Activities on Retention

EFFECTIVENESS OF STUDY ACTIVITIES ON RETENTION
LABORATORY SIMULATION

RUN NO. SP663.SP197.5.4. WILL WUNDT STUDENT NUMBER 101

POTENTIAL VARIABLES	CHOICES FROM POTENTIAL VARIABLES CONDITION 1	CONDITION 2	CONDITION 3	CONDITION 4
STUDY ACTIVITY	UNDERLINING	UNDERLINING	UNDERLINING	UNDERLINING
MATERIALS SUPPLIED	INSTRS OUTLINE	INSTRS OUTLINE	INSTRS OUTLINE	INSTRS OUTLINE
MATERIALS TESTED	NO CONTROL	NO CONTROL	NO CONTROL	NO CONTROL
YEAR IN COLLEGE	NO CONTROL	NO CONTROL	NO CONTROL	NO CONTROL
TEST TYPE	OBJECTIVE	OBJECTIVE	OBJECTIVE	OBJECTIVE
GRADE POINT AVERAGE	2.0 - 2.5	2.0 - 2.5	3.0 - 3.5	3.0 - 3.5
LEVEL OF COURSE	NO CONTROL	NO CONTROL	NO CONTROL	NO CONTROL
HOURS STUDIED	2-4 PER WEEK	6-8 PER WEEK	2-4 PER WEEK	6-8 PER WEEK

SUBJECT	RAW SCORES CONDITION 1	CONDITION 2	CONDITION 3	CONDITION 4
1	27.	41.	30.	36.
2	23.	27.	27.	42.
3	22.	40.	40.	45.
4	37.	40.	33.	40.
5	18.	35.	31.	49.
6	33.	32.	40.	50.
7	16.	30.	25.	45.
8	32.	34.	33.	40.
9	38.	43.	45.	45.
10	28.	38.	34.	38.
MEAN	27.40	36.00	33.80	43.00
STDEV	7.63	5.25	6.23	4.59

DIAGNOSTIC MESSAGES
GOOD EXPERIMENT DESIGN
$ 25.00 HAVE BEEN CREDITED TO YOUR ACCOUNT

EXPENDITURES

INITIAL BALANCE	$ 910.50
SUBJECTS	$ 10.00
CONTROL OF VARIABLES	$ 40.00
COMPUTER TIME	$ 2.0
TOTAL	-$ 52.00
BONUS	+$ 25.00
FINAL BALANCE	$ 883.50

assigns the simulated subjects to levels of the variable based on a sampling of a normal probability distribution.

Any of three types of potential independent variables may be included in each model. Discrete variables, such as presence or absence of a treatment, are most obvious. The model file must contain an effect for each level of each discrete variable and a beta weight. Continuous variables, such as the number of trials, may also be represented. The third type variable is range. An example of a range variable is IQ. The student must specify an upper and lower limit in order to control or manipulate a range variable; LABSIM samples a normal distribution in an attempt to obtain a sufficient number of "subjects" whose range-variable score is within the range specified by the student. If it fails to find enough subjects before exceeding a criterion value, the experiment fails to be completed and an explanatory comment is printed.

LABSIM also evaluates the adequacy of the student's design. For example, if the student attempts to manipulate more than one variable in a two-group design, an appropriate error message ("more than one variable was manipulated") is printed after the data have been listed.

The number of simulation attempts, the number of successful experiments ("good designs"), and the credit balance for each student for each model is maintained in the STUDREC file. This information is easily available to the instructor through the UPDATE module.

Students find LABSIM simple to run from a terminal; after one or two runs, they usually can generate a complete experiment in about 4 or 5 min. In most respects, LABSIM simulations are easier to run than EXPER SIM simulations. Indeed, my most frequent users are not the relatively sophisticated students in the research methods class, but introductory psychology students, most of whom lack computer sophistication when they enter the course.

All of these features show LABSIM to be an exceptionally well-designed simulation program. Its greatest strength, however, lies in the simplicity with which new experiment models may be created.

Thus, with no prior experience in model building, I set up seven models in a period of a little less than 2 months. The time involved in the creation of a data file for a model ranged from about 2 weeks to 2 days. After this practice, it was possible to set up the last model ("The moon illusion"), now on-line and working reasonably well, in a little over 2 h. That does not, of course, include the literature search and modifications that usually have to be made after student testing. Nonetheless, for a person with as little computer expertise as I have to construct these models in that short time testifies to the simplicity and ease with which LABSIM can be implemented, expanded, and developed for whatever purposes an instructor might desire. LABSIM is not only student-oriented system, it is instructor-oriented as well.

LABSIM III

The version of LABSIM discussed so far is a relatively limited one obtained from Edwards (Note 1) and modified for interactive use. It is LABSIM II (LABSIM I, I take it, is of the same class of objects as the APPLE I).

More recently, Edwards (Note 2) has developed a greatly enhanced version, LABSIM III. In addition to doing everything that LABSIM II does, LABSIM III (1) is modular and developed with transportability in mind, (2) has a more extensive student monitoring system, which includes records of the types of designs submitted and the types of errors that may have occurred, (3) is capable of handling three-factor experiments with up to 18 groups and three independent variables, (4) allows for six types of data transformation, (5) provides a complete analysis of variance summary (where appropriate), including plots of treatment means for all main effects and interactions, plus tables of sums, means, and standard deviations for each cell in the analysis, (6) will be accompanied by complete internal and external documentation, including a programmer's manual, an instructor's manual, and a student manual.

AN EVALUATION

My experience with LABSIM has been immensely satisfying and students appear to like it. Other instructors in our department use it in many classes other than the research methods course.

More specific data regarding its use and evaluation are available from the author. This term (half over when these data were collected), about 500 LABSIM simulations have been successfully run by the 200 or so students enrolled in the research methods class and in various sections of introductory psychology. If this trend continues, well over twice the assigned number of runs will have been completed by the end of the term. These figures reflect the enthusiasm of our students about these models, and the enthusiasm is also apparent in classroom discussions, questions, and other comments related to the models.

In the past, the average connect time per student per LABSIM run has been about 9 min. Given that students perform slightly over two experiments per sitting, this represents an average time of 4.5 min per experiment simulation.

End-of-term student evaluations of the LABSIM models have been almost uniformly favorable. Most students feel that the simulations make a significant contribution to the class, and statements like "the computer simulations were excellent" or "really enjoyed the computer experiments" have been common.

SUMMARY

LABSIM is a new and unique general-purpose computer-based simulation program. It is characterized by ease of use and ease of understanding by students, simplicity of implementation by instructors, and versatility in function. Because it is a data-driven program, it requires no computer expertise to construct new experiment models. This feature allows instructors to quickly and easily develop models for instruction about substantive content in a wide variety of areas, as well as for instruction in research design and statistics.

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