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AUTHOR Seidel, Robert J.; Kopstein, Felix F.
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ABSTRACT

Resource allocations, in terms of funds, people, facilities, and the delegation of appropriate authority to formulate appropriate policy, for research and development and implementation of computer-assisted instruction are discussed in this paper. A description and justification of CAI as a technology is included. The need for incorporating a systems approach to educational innovation is stressed. A partnership among industry (profit and nonprofit), government, and education is suggested as a model, and a national network of multidisciplinary centers is advocated as the vehicle for accomplishing the goals of research, development, and implementation of effective and efficient CAI systems. A reference list is appended. (JY)

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Resource Allocations to Effect Operationally Useful CAI

by

Robert J. Seidel and Felix F. Kopstein

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Prefatory Note

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RESOURCE ALLOCATIONS TO EFFECT OPERATIONALLY USEFUL CAI

Robert J. Seidel and Felix F. Kopstein

INTRODUCTION

The broad picture of resource allocation for research and development (R&D) and implementation of computer-administered (or computer-assisted) instruction (CAI) will be discussed in this paper. Specific cost projections within an operational setting have been discussed previously (Kopstein and Seidel, 1) and therefore will be dealt with only briefly. "Resource allocation" will refer to funds, people, facilities, and the delegation of appropriate authority to formulate appropriate policy. And the fact that all these many resources—government, industry, and education will be considered—means that inevitably politics and economics will be intertwined in the subsequent discussion.

The features of this paper will include a brief description and justification for CAI as a technology. The need for incorporating a systems approach to educational innovation will follow to set the proper framework for the magnitude and complexity of the required research and development effort. An analogue to a corporate level of investment in research and development, 3% to 5% of income, is proposed to effect the orderly transition of CAI from "breadboard," through prototype, to an operational system.

Problems that arise in the course of considering appropriate resource allocation stem in part from the fact that none of the so-called entities—government, industry, or education—are monolithic. Government involvement will be both central and local. Industry in CAI includes hardware manufacturers, book companies, and so forth. Education includes central and regional administrators, teachers, research and development personnel, as well as the ultimate user, the student. Problems of program management and coordination are thereby made difficult.

Finally, a partnership model will be proposed to evolve operational CAI. The vehicle of a national R&D center with regional satellites is suggested both to provide proper training and to permit flexibility of research approaches to accomplish the goal of operational CAI. These points are discussed in the context that: "anything worth doing is worth doing right."

Thus, we will ask if research and development into CAI is worth expenditure of money, time, and effort. As you might predict, our answer will be affirmative. Granted this is so, what expenditures are necessary to "do it right"? Finally, how should the resources be properly allocated among industry, government, and the educational community to bring CAI to fruition? Fruition in this case refers to the actual production of multiple copies of operational CAI systems usable in schools and universities throughout a nation.

THE FRAMEWORK

CAI—A Necessary Technology

Various prominent individuals and agencies in the United States have indicated the need and desirability of making use of the educational opportunities inherent in individualized instruction. The Committee for Economic Development has represented the broadest cross-section of U.S. society in its appraisal (200 businessmen, educators, psychologists, and community leaders). In essence, they present a convincing case for a failure of our current educational system to take advantage of modern technology and to deal effectively with the increasing requirements of our complex society. The Committee has pointed out that "individualized instruction geared to the individual interests, abilities and learning rate is one of the cherished goals of American education. It is an aspiration which we wholeheartedly share, yet the schools are making very slow headway in this direction through present means . . . " (2). Psychologists have been engaged in the study of individual differences for years. Teachers have long been complaining of the inability—administratively—of coping with students as individuals and have been thereby forced to teach, for the most part, to the mean of a class.

Our view is that CAI is the leading, operationally defined edge of a model of individualized instruction. It represents the *potential* (with all due respect to objection by Oettinger and Marks (3)) for a quantum leap in adapting instruction to the momentary needs and capabilities of the individual student. It provides the basis for an iteratively improving instructional environment.

A word should be added here about the distinction between technique and technology. The criteria for evaluating them differ. One technique may be properly compared to another within the same system model. Teaching reading by the phonics method versus "look and say" is an example of such a comparison. Indeed, studies have been conducted attempting to hold all other components of the momentary education system constant save the difference in technique.

In evaluating a new technology, however, such relatively clear and simplistic comparisons are insufficient. It may well happen, as with CAI and individualized instruction in general, that the system in question must be redefined. It is silly to mold a computerized, individualized teaching environment around a six-hour day. It is also improper to consider the economics of the new technology in terms that neglect the new opportunities opened up and hitherto impossible. To quote Harley, "When economies result [from using the new technology] they are derived from the reduced cost of providing additional services--from the improvement in the quality of teaching and the level of learning; from the ability to shrink time and space, and from the sharing of limited resources," (4, p. 56).

CAI is thereby a technology, not a new experimental classroom technique. Indeed, the magnitude of societal effect possible with CAI may be compared without any hesitation, to that of the industrial revolution. The potential for basic improvements in educational systems exists, but it must be brought to the proper climax. The economic exploitation, frustration, disruption of employment, suicide, and so forth, which the industrial revolution led to, could have been avoided with proper planning. With the advent of the computer, automation has already changed man's role to that of innovator rather than routine performer. On a purely rational basis, therefore, CAI is worth doing wherever individual differences make a difference in the field of instruction.

CAI Research and Development is Complex

Having answered, all too briefly, our first question affirmatively—that is, CAI *is* indeed worth doing—the second and more thorny question must be addressed. What do we mean by, "It should be done right"? Figure 1 shows Eight Steps that comprise a total systems approach. This framework (with slightly different words, or with seven versus eight steps) must be followed from research through development and implementation in order to result in operationally valid and useful CAI systems.

The Eight Steps of the Systems Cycle

1. State the real NEED you are trying to satisfy.
2. Define the educational OBJECTIVES that will contribute to satisfying the real need.
3. Define those "real world" limiting CONSTRAINTS that any proposed system must satisfy.
4. Generate many different ALTERNATIVE systems.
5. SELECT the best alternative(s) by careful analysis.
6. IMPLEMENT the selected alternative(s) for testing.
7. Perform a thorough EVALUATION of the experimental system.
8. Based on experimental and "real world" results, FEEDBACK the required MODIFICATIONS and continue this cycle until the objectives have been attained.

Figure 1

A proper operational CAI system must pass from the breadboard stage, through the prototype, to an operational, cost/effective phase. "Breadboard" is a term originated by electronic circuit designers. During very early stages of developing an electric circuit the paper design (conception) is translated into a set of components provisionally connected (by alligator clips and a few wires) and tacked onto a wooden board. The purpose is to verify that the design scheme will have the general characteristics expected of it. By extension, "breadboard" refers to any first and provisional realization of a system design.

Applied to CAI, documents like the CED (Committee for Economic Development, July 1968, 2) report have stated the *need* in education for making maximum use of individualized and personalized instruction. We have defined our *objectives* in terms of producing student output at a given level of achievement. As part of the design, note that this process is to be an iterative one in attaining that goal. In the breadboard iteration, only the most crucial design criteria are applied. Secondary objectives, that is, desirable features or "nice-to-have" characteristics, are kept from confusing the basic design problem. For example, with reference to CAI, at the breadboard stage it is inappropriate to consider time-sharing the computer with batch-processing operations.

Similarly, during the breadboard stage of design, operating *constraints* are minimized. In terms of CAI, it may be essential to develop inexpensive student terminals, but first terminals with adequate characteristics must be designed. Further limitations stem from available computers and compatible CAI equipment and languages. Current CAI systems are divided among those which have not progressed past the breadboard stage and those which have tried (unsuccessfully) to bypass this stage. *Alternative* instructional decision-making strategies and mixes of hardware and software subsystems with selected subject matter must be considered. Following systematic evaluation and study of the alternatives, *selection* of an initial system is made and *implemented* for a test run. *Evaluation* is made based on student output. *Feedback* to improve (modify) iteratively the CAI system, namely, meeting objectives, is made.

This process continues throughout the iterative development in order to refine the system. Once the breadboard phase has been completed, it is possible to proceed to a prototype system design, the circumstances under which the system must perform. In this phase one first establishes precisely what the system is to do, taking into consideration major constraints such as permissible costs or delivery time. Various available means (e.g., magnetic or optical information storage) are weighed against optimization criteria. Optimization means a best compromise among contradictory objectives and imposed constraints (e.g., lightweight, portable student terminals with character-video-audio display capability for no more than $500 per unit) in terms of some ordered set of criteria (price more important than display capability, which is more important than portability). Finally, the design plan that has emerged is implemented and a first prototype is synthesized. A prototype CAI system may have operational usefulness, but is likely to include design flaws and oversights that ought not be multiplied in many duplicated installations. A prototype is merely an untried and unadjusted assemblage.

A tested system emerges over a number of subsequent repetitive development cycles. In the case of a CAI system, only a small number of students would be exposed to its instruction initially. Their interactions with the system must be minutely monitored and appropriate adjustments made. Massive data need to be collected in order to determine whether the prototype is actually performing as envisioned.

Where actual and expected performance disagree (e.g., mean delay of system response to student exceeds stipulated value of one second) revisions must be made in the system design. A tested system exists only after observed system performance coincides with expected performance. Only then is it economically justifiable to use the prototype design as a template for multiple reproductions.

This approach is also necessary when attempting improvements in a traditional instructional model. We shall return and enlarge upon this approach later when proposing a scheme for accomplishing proper CAI development. The significance of the approach is amplified tenfold with an innovation as encompassing as CAI can be. The framework then does not preclude CAI as drill and practice, simulation, or use as strictly a calculational aid for problem solving. These can all be useful parts of an overall CAI R&D project. However, as previously noted, the instructional system consists of N components. If only one or two components are clearly identified, measured, and controlled, their contribution to instructional output relative to that of all the N-1 or N-2 other uncontrolled components becomes extremely difficult, if not impossible, to assess (5).

"Doing it right" thus means having a careful system research and development effort integrating the facets of computer hardware and software with content development and studies of alternative instructional strategies. This means, in turn, a multidisciplinary effort. If CAI is to fulfill the promise of delineating the relative importance of the various characteristics pertinent to appropriate decision-making in instruction, it must have the opportunity to model the instructional situation, to vary parameters, and to apply these to meaningful human learning.

The Amount of Required Effort for CAI R&D is Large

Let's consider what experience to date has shown to be the requirements of large-scale CAI centers for annual funding levels. From informal discussions with knowledgeable persons regarding their CAI projects' fiscal problems, it appears both internationally[1] and in the United States that an operating budget of approximately $250,000 to $300,000 a year is necessary merely to maintain facilities in operations. The reason for this becomes quite clear if one considers simply the rental price of an IBM 1500 system as an example. The hardware alone averages $100,000 to $110,000 per year. Taking the $250,000 total, this leaves $150,000 per year for staffing, administration, and support facilities. The result is that, given approximately $38,000 cost per professional man-year, one can have only a minimal CAI program (4 professionals) concentrating on operational activities. If research is to be conducted at a CAI center in a university or other academic institution (where most CAI R&D seems to be taking place), it must depend

[1] Mr. Andre Kirchberger, Administrator, Center for Educational Research and Innovation, Organization for Economic Cooperation and Development (OECD), Paris, France.

inevitably upon part-time participation of faculty, students, and administrative personnel. Most of these individuals have other primary responsibilities demanding the major part of their energies and attention.

How much, then, should a total systems approach toward the development of CAI require to produce an operational, useful example of individualized instructional models? We cannot answer this in absolute terms, but on the basis of experience with Project IMPACT's[1] multidisciplinary staff involving 18 professionals and seven others in supporting roles, a personnel budget of at least twice these amounts seems necessary. Our installation is unique in that it is funded, so far, by a single arm of the government. Of course, one of the problems for most of the CAI projects is that they are funded from multiple sources with different demands; and in order to satisfy the requirements of the various funding agencies, the research and development is fragmented. Until recently, the awareness of funding at a "critical mass" level did not seem to exist. Recently, it seems that the U.S. Office of Education has taken steps to support fewer projects in CAI but at a higher level of funding. This seems to be a move in the right direction. The problem, however, in maintaining this critical level is not simply to permit existence of an operating environment, but rather to facilitate large-scale, integrated centers to study and arrive at both the adequate descriptions of learning processes and the necessary prescriptions for instructional development.

A recently published figure from the Bureau of Research, U.S. Office of Education (6), indicates that they are providing an average of approximately $287,000 per project over 10 CAI projects. If other governmental agencies could support these *same* projects, without changing their goals and with a comparable amount of money, then it would seem to be possible to proceed beyond the breadboard stage of CAI development.

A point of clarification is worth noting with respect to encouraging flexibility and diversity in approaches. The advocacy of varying approaches to solving the strategy development and overall construction of useful CAI should not be in any way misunderstood as the support of multiple small-scale efforts. Furthermore, if a funded project is required to continually submit and resubmit a multiplicity of proposals, a large amount of time and effort will go into nonproductive work. A rational basis for selection of project proposals should be used at the outset, and then a reasonable amount of funding be provided over a period of at least five years. Without advocating that all the eggs be put in one basket, we are saying that the highest rate of progress is likely to result from a distribution of available funds to fewer "baskets" at sufficient levels to permit large-scale integrated efforts. On the other hand, funding a diversity of projects at very small levels will probably result in none of the efforts providing a full-fledged operationally, implementable CAI system for education.

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[1]HumRRO Work Unit IMPACT, Prototypes of Computerized Training for Army Personnel.

RESOLVING THE PROBLEMS OF NECESSITY, COMPLEXITY, AND MONEY

An Analogue to the Corporate 3% to 5% Investment is Advocated

What expenditures should be invested in a CAI total systems effort? We can start by taking a cue from a corporate model and note that a number of sources (Duckworth of the United Kingdom, 7, as well as representatives of corporations in the United States) have indicated a 3% to 5% level of corporate income is appropriate for these purposes. In 1960, the amount spent in education was approximately .1% (Coombs, 8). Recently, it was estimated that in 1968 the entire educational enterprise in the United States cost somewhere around $50 billion[1]. The figure for expenditures on educational research now reaches approximately $100 million, a .2% investment. Perhaps some would find cause for optimism in this increase. However, even with a large error factor, it appears "that the investment in educational research is only a fraction of 1% of the educational enterprise." In contrast to this, R&D investment in the electrical communications industry in 1968 stood at approximately 3.4%. IBM reportedly invested $300 million, or roughly 5%, in R&D of its reported $6 billion gross income for the same period.

If we accept the 3% to 5% figure as necessary to sustain viable R&D in education, the annual dollar investment, given the $50 billion total year expenditure, should have been between $1.5 and $2.5 billion. Before you cringe at the apparent enormity of this amount, consider it relative to other innovative programs. The United States has put a man on the moon. The United States has invested approximately $24 billion and 10 years of research and development to go from the breadboard stage through the prototype to the ultimate system for the lunar landing and retrieval. Accepting the 3% to 5% figure, a comparable time period for innovative developments in education would amount to an investment between $15 and $25 billion. We need to consider this question: Is education any less valuable than a lunar landing or space travel in general? Our personal reaction is that both efforts are extremely valuable.

Let us carry the analogy one step further. The dollar cost of investment in education, in particular in CAI, further pales by comparison to the costs of other single technological developments. For example, the U.S. government's contribution so far to the controversial supersonic transport program is roughly $1 billion. The cost of the deep-dive nuclear research submarine is roughly $99 million. Many more such examples could be cited. Note that these are specific system efforts. We have previously documented that an implementable computer-administered instructional system, following from breadboard through operational development stages, could be accomplished for something

[1]Arthur S. Melmed, "CAI—A Five-Year Perspective," a symposium presentation at American Educational Research Association meeting (mimeographed copy), Los Angeles, February 1969.

in the order of $5 million in a careful time-phased schedule (Seidel, 9). We submit that this is certainly not off by more than a factor of two, and further that the value of such a development, as we have tried to indicate, can be monumental in reshaping the whole field of education. Of course this must include adequate interdisciplinary staffing and evaluation and testing of all the components of experimental hardware, computer software, instructional strategy, and various selected subject matter. However, we submit again that the expenditure is but a minute fraction of the cost for other technological developments. Surely the goals are at least equally desirable. Also, given the 3% to 5% investment in all of education, enough money should be available for such innovative efforts as CAI to permit, as Oettinger has proposed (2), a great deal of flexibility and diversity in approaches. It thus should be possible to solve the educational technological problems of using the computer properly in the entire field of instructional and educational improvement.

A Proposed Partnership: Allocate the Unique Resources Among the Steps of a Systems Approach

It seems clear that we are faced in education and training with (a) a commitment to unprecedented financial investment, (b) the requirement that this effort serve the public welfare, vis-a-vis the educational consumer, as opposed to a private corporate entity and its stockholders, and (c) the recognition and acceptance that the return on investment may take much longer for accurate calculation than do industry's profit and loss statements. All of this indicates that only the Federal government can adequately and properly provide the funding (and thereby influence the policy guidelines) for this type of partnership.

Secondly, the techniques of industrial research and development (i.e., product development) are appropriate to contribute to an evolving CAI system. Various industries have the facilities and the tools for development and production (certainly for the necessary hardware and software components in CAI). Non-profit industry employs research personnel. The educational community is a unique partner in the sense that the local school system and its personnel are going to be the focal point of the development, but they do not have the financial resources nor do they have more than a portion of the total personnel required to accomplish this innovation properly. Their partnership contribution consists in developing instructional content through providing subject-matter experts as part of an interdisciplinary team, and by providing the demonstration and test facility within which the innovative experimentation and development can take place.

Finally, in addition to the partnership structure, the developing CAI effort must include, as indicated earlier, a functional approach that embodies systems design and total systems development using the eight steps.

To place the partnership within this approach, the initiation of policy and guidelines (statement of *need*) would come from a central government agency. (It is conceivable that in a somewhat different form, specific needs might arise from statements within the educational community.) These would be transformed into specific system *objectives* jointly by team members representing all these arms of the partnership. An interdisciplinary research and development effort (comprising the remaining steps except *evaluation* and *feedback*) would be conducted with the lead role most probably taken by a non-profit (rather than profit-oriented) R&D corporation (see last two pages for reasoning). Local government and educational system personnel and facilities would provide administrative aid. Industry would fabricate the necessary hardware and software, and members of the three-way team would then attempt to *implement* the provisional system. At this stage, the work primarily would be accomplished by industry and the educational community with administrative aid provided by local government (Figure 2).

Functioning Model in the Systems Cycle

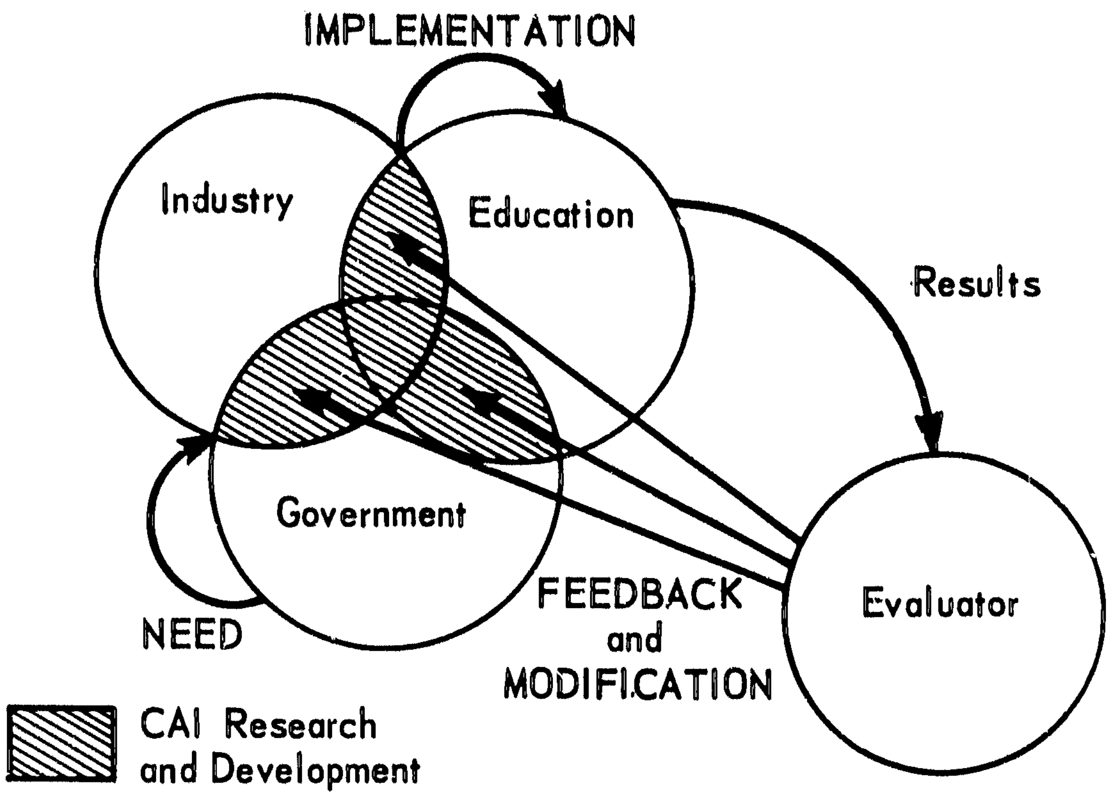

Figure 2

Considering the possibility of this joint venture as indicated, one more important link must be added. To provide the necessary objective *evaluation* and *feedback* in a coordinated manner, an independent fourth party is required. The form of the feedback information would be appropriate to the particular partner of the three-way team in order to make appropriate modifications to those aspects of the systems development process uniquely under its jurisdiction. For example, if modifications were required regarding statements of need, this could be provided to the policy and guideline process for the government. As the modifications were necessary in fabrication of equipment and software, it would be given in unique form to industry, and so forth.

While this may be difficult to conceive of within a given country, it may not be far off from what is currently proposed by the Organization for Economic Cooperation and Development (OECD), an international body to establish policy and make apolitical, dispassionate and objective evaluations of CAI studies. In the United States fragmented examples are beginning to appear.

PROBLEMS TO SOLVE

Problem of Interpreting the Value of Education

Now we shall return and perhaps answer some of the rejoinders that may have developed to our proposal of a reasonable level of dollar investment. Let us consider the fact that the goal of a space program such as putting a man on the moon and retrieving him is quite specific. The parameters for guidance, for control of the entire system required to perform this feat, although large, are finite, measurable, quantifiable. A major problem for education is to identify all those factors that are pertinent to estimating requirements for specified achievement characteristics, and also for interpreting the value of that educational achievement.

Another paramount problem that educational technology faces when contrasted to a neat and closed engineering technology such as the space program, is that the return on investment on education may not be visible for roughly an entire generation. The attainment of objectives in the space program, on the other hand, was relatively immediate, dramatic, quite tangible, and rapid. Our only rejoinder is that in educational technology one must extrapolate from immediate criterial effects of measured educational proficiency to ultimate criteria of general societal significance. Of necessity this means at the outset that we have clearly identified the parameters, our educational inputs and our educational outputs.

We must not permit our experience with the ambiguities and vagaries of the traditional educational instructional system to force a premature and inappropriate evaluation of computerized instruction. True, there have been difficulties in measuring a "good" teacher, certainly in traditional instruction one of the most significant educational inputs (Froomkin, 10). But, as noted previously (Kopstein and Seidel, 1; Seidel, 9; Seidel, 11), in computer-administered instruction we can objectively document the dimensions of that system. Cost effectiveness *can eventually* be measured. The instructional agent's value (instead of the human teacher's) *can* be measured against its output (student achievement). The costs of the entire CAI system, input, transformation and output, *can* be evaluated and justified or not, on tangible and objective bases.

What then are the implications for consideration of cost effectiveness studies in CAI? Granted that we may extrapolate to later generation returns, it certainly seems we must consider *direct* outputs of the instructional system if our evaluation is to have any substance at all. Standardized achievement units must be the criteria (Randall and Blaschke, 12). Harley (3, p. 52) in an insightful appraisal makes the point even stronger. " . . . we have been concerned with the cost per student taught (our input) and not the cost per student learned (our output); yet we know that what is taught and what is learned are not synonymous." We have ignored therefore the vital " . . . cost of our scrap (non-operable units)—students who cannot function in today's society . . . " and therefore our cost statements have fallen far short of the true costs of our education system.

A host of other problems beyond the scope of this paper relate to establishing other measurable values of education. For instance, Suppes (13, p. 12) has recently called for "clearly stated normative principles" for dealing with the contradictions in modern philosophy of education. While not a direct concern of economics and CAI, certainly resolving the existing antonyms of educational philosophy (e.g., maximum freedom of choice versus development of a sense of discipline, content versus method, social adjustment versus maximum achievement) is essential for a meaningful evaluation of *any* educational innovation. This is particularly critical (perhaps propaedeutic) for CAI which depends upon acceptance to a large degree of the model of individualized instruction. We believe that it is an extremely important problem to be resolved.

Problems Exist in Establishing a Potential Partnership Model

Another item is equally important in establishing that CAI is valuable, and when setting the necessary dollar figures for R&D investment. That is, what kind of a workable framework can exist, within which this research, development and operational environment is appropriate? Can industry, government and the educational profession be combined to bring the effort to fruition? What policies must be incorporated to bring this about? How can resources, money, facilities, personnel, and time be most appropriately allocated?

Are Goals Compatible?

Before delineating the proposed prototype for the three-way partnership, let us examine potential problems that may arise from the combination of industry, government and educational professions in this manner. One can ask whether the model of research, development, and operational utility for industry is compatible either with the educational profession or with that of the government. Interestingly, we already have at least one failure in an attempt to bring these three entities together. Project ARISTOTLE was intended to be a catalyst and continuing stimulant for educational innovation through these three arms, and it has been dropped for lack of support. Perhaps the answer lies in incompatible models. Industry in the United States exists to manufacture and sell at a profit. Its investment of 3% to 5% in research rests clearly in the belief that the return will occur in a relatively short period, perhaps two to three years. The premise becomes muddied when this industrial template is applied to education. We spoke earlier of the generation lag for evaluation purposes in educational products.

Considering the educational model, the goals of education have never been defined in terms of profit and loss statements. Selling a product has never been part of the system. In fact, a frequent criticism in recent years has been that the intellectual aspects of education were being subverted for more specific and practical occupational training.

It seems that the traditional roles of industry and the educational profession are so antagonistic, or at least not overlapping, that throwing them together without creating a new compatible model for R&D purposes in CAI is to create an anomaly doomed to failure at conception. Moreover, government and education are interested in welfare of the populace, education being—in this sense—a subset of the governmental function. Industry is concerned with product development and sales. But need these be different? (Galbraith said in *The Affluent Society* that the private sector could not handle this type of effort on its own, but why not a partnership?)

"Government, Industry, and Education" Are Not Monolithic Entities

The so-called education "industry" in CAI is not monolithic and not coordinated. It involves hardware manufacturers, book companies, and computer software houses at the very least. The companies are *relatively* independent with their own profit and loss statements, corporate policies, and so forth, and they all must be brought together in order to construct a meaningful CAI system. The educational community and the government are also made up of components with differing capabilities. "Educational community" consists of at least administrators, middle management in the person of assistant principals (or assistant headmasters) and the teachers on the one hand. On the other hand is the ultimate user, the student. Government is represented by central and local spheres. For funding, we require federal assistance and for participation in implementing CAI, we require local involvement.

There may well be many objections to a proposed cooperative set of overlapping functional relationships among industry, government, and the educational community. Not the least of these is an abhorrence at attempting to apply the corporate model of R&D to education. But we ask the question: Why not? It has produced inventiveness, increased profits and viable, new products in the marketplace. Why not ask the same of education R&D?

Will the corporate model apply? If education is to be considered as is industry, it is peculiar in that the financial resources are clearly not within the system per se, but must be provided by outside sources—the local, regional, and central governments. Recently, this has been called into question by those who would like to apply the corporate model (13); but the alternatives are not being readily accepted (they imply clear, behavioral definitions of educational objectives, etc.) by the educational community.

This difficulty is epitomized in a statement by a noted special assistant on education who was in the former presidential administration—"Perhaps the most traditional . . . , and the one (local community) most resistant to outside change has been the educational community" (14). The purpose of the Elementary and Secondary Education Act of 1965, Title III program, is to provide federal grants directly to local schools " . . . for the very purpose of stimulating innovation and change in local educational patterns." The prevailing mood, however, has been deep-seated suspicion in the United States that federal aid means federal control. Consequently, a serious question is: Even given sufficient funding resources, how can a workable cooperative model be developed to ensure (a) valid R&D involving the educational community, and (b) proper implementation in local systems. *Part of the solution must of necessity involve commitment of dollar and personnel resources toward large-scale R&D efforts in CAI and toward massive training and retraining in the educational community.*

Let us turn the question around and ask: Is education becoming an industry? Should it be? The problem would seem to be one of retaining the goals of intellectual expansion, freedom, and innovation, while adopting where feasible, a model of improvement in education drawing upon the techniques of industrial development. What also seems to be required at the very least are policy guidelines from the federal government to force a necessary workable structure. Assuming that the policy is appropriate to the task, this would aid not only industry, but the educational profession and the educational user--the student.

A Vehicle for CAI Research, Development, and Implementation is Proposed

A definite means by which the proposed partnership could proceed efficiently is the last item we will discuss. Within the United States, there are two such vehicles. We propose first the establishment of a national center for research and development on innovation in educational systems. (We compliment the Center for Educational Research and Innovation that now exists in France.) We think it is necessary to establish such an institution. In fact, this has been proposed previously for the U.S. Navy Department, but was not funded by the Department of Defense. The Center's prime function would be to coordinate the application of diverse scientific and technological principles in the solution of educational problems and, generally, to evolve educational technology to higher and higher levels. At any rate, this center would have closely tied regional satellites to carry out the translation of the results of the research and development into operational reality within local school systems. The fourth element, *evaluative* entity, described earlier, fits here. It would be this entity that would bring together the industry, central government funds, and local governmental and educational systems for reorienting personnel into a demonstration program.

At the national center a training emphasis would be given to pre- and post-doctoral levels in order to develop increased national competence in instruction theory. The areas to be included might be illustrated by Computer Sciences, Behavioral Sciences, Applied Mathematics, in general what we might call educational-technological research, technical writing programs, and so forth. On the regional level, the regional centers would train for tasks relating to the implementation of CAI, that is orienting communities, training local officials, local administrators of programs, and so forth. It is important to make clear that the national R&D Center will not be the sole technical, or active research, installation. Research and development would be carried on at local installations to permit flexibility in approaches and there would be technical feedback or input in both directions to upgrade the R&D status in general. A plan for coordinated activities among the regional and the national centers would be essential to avoid fragmentation and lost efforts.

To accomplish testing and implementation there already exists a potential prototype of a fourth party in the United States. It is a nonprofit corporation (the Institute for Politics and Planning) which has the role of bringing together government, industry, and educational systems. This takes the form, for example, of establishing advanced learning centers in conjunction with the government, in this case not only the central government as the funding source but the local governmental groups as well as the local educational system participating as members of a testing and evaluation team. (Currently the profit-minded industry operates on a fixed-fee basis, and gets paid if, and only if, students succeed in reaching established achievement criteria.)

This effort is somewhat premature with respect to CAI because it assumes that we are now able to accomplish CAI implementation on a large scale. Nevertheless, a nonprofit corporation may well be the focal point for making a partnership viable regarding all the activity phases, research, development, and implementation. In the nonprofit corporate model, goals tend to be more directly oriented toward the welfare of society than those of the profit maker who must put survival first. Alternatively, it may be possible to adjust the goals of the profit corporation. If the return on investment cycle were extended (to five or more years) through the provision of some type of government "insurance," profit-making industry could play a role equivalent to the nonprofit entity. The "insurance" debt could be retired at the end of some agreed-upon period either out of the corporation's assets (if no marketable product was delivered) or as a percentage of the profits derived from an implemented product. This at least represents one mechanism to consider.

In any event, the partnership model would have to encompass all the facets of research, development, and implementation. Too frequently, an innovation is developed and implementation is given short shrift in the form of simply a written recommendation. To quote Mr. S. Clark Beise (Chairman, Executive Committee, Bank of America) in the report on innovation in education from the Committee for Economic Development, "One of the major problems inhibiting change in our present educational programs and processes is the lack of communication between educators, teachers, administrators, school boards, and the public."[1] He goes on to note that the statement in the report by the CED develops a program that should be accomplished for research in innovation but does not carry the recommendation through sufficiently "to the point of being

[1]Platt, a systems analyst, adds the dimension of unawareness " . . . of the investment aspects of education . . . " to the problem. He describes the public and private school system as a " . . . network with very few nodes sufficiently concentrated to allow one to enter and perturb the system." (15, p. 417) It seems our task, then, is to create the requisite nodes!

able to demonstrate their value to those who must be convinced that changes should be made. *In order to disseminate information on recommended changes effectively, there should be established a system of demonstration schools, reasonably available geographically, to show what can be done in general practice to implement and integrate the recommended improvements, within practical costs, into a rounded program."* (Italics added.)

We trust also that this discussion has demonstrated that "CAI is worth doing," and that the approach proposed herein has suggested a reasonable framework for "doing it right." We are certain that alternative proposals can and will be made to deal with the complex problems of resource allocation for CAI research, development, and implementation. The rough sketch given in this paper can be viewed as no more than an opening wedge. However, we are equally certain that some such approach must be put forward and developed as a workable model if CAI is to live and fulfill its vast potential.

Although we have been concerned with the field of education, this discussion generally applies to training and CAI also. To the extent that training can represent a more well defined subset of instructional processes (e.g., objectives and achievement measures) then the task of moving from research through development to operational CAI is made easier. But the steps are the same, the required commitment is firm, and the goals are still waiting to be achieved.

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13. ABSTRACT

Resource allocations, in terms of funds, people, facilities, and the delegation of appropriate authority to formulate appropriate policy, for research and development and implementation of computer-assisted instruction are discussed in this paper. A description and justification of CAI as a technology is included. The need for incorporating a systems approach to educational innovation is stressed. A partnership among industry (profit and nonprofit), government, and education is suggested as a model, and a national network of multidisciplinary centers is advocated as the vehicle for accomplishing the goals of research, development, and implementation of effective and efficient CAI systems.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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CAI Technology						
Computer-Administered Instruction (CAI)						
Computer-Assisted Instruction (CAI)						
Instructional Media and Techniques						
Programed Instruction						
Resources Allocation for CAI						

Unclassified

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Footnotes

1. The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare to the Learning Research and Development Center, University of Pittsburgh. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions do not, therefore, necessarily represent official Office of Education position or policy.

2. Requests for reprints should be sent to Wayne Donaldson, Department of Psychology, University of Pittsburgh, Pittsburgh, Pennsylvania, 15213.

3. Throughout the paper $\underline{d}'$ is to be interpreted simply as the distance of the ROC curve above the chance diagonal as measured at the point of intersection of the ROC with the negative diagonal. When the term is used it will always be clear, usually through pre-modification, whether it comes from recall or recognition procedures. For recognition studies this is the standard definition of $\underline{d}'$. For recall data it is equivalent to what Clarke, Birdsall and Tanner (1959) label $\sqrt{d_e}$. In a later section of the paper $\underline{d}'$ is modified as being forced-choice, the definition being in the text. While the interpretation of $\underline{d}'$ may differ depending on whether the ROC is derived from recall or recognition data, it is just that question of interpretation that is being examined here and consequently $\underline{d}'$ will be used throughout only as a descriptive statistic.

Figure Captions

Figure 1 $\underline{d}'$ as a function of trials for all groups in Experiment I. Also plotted is $\underline{d}'$ as a function of trials for the group receiving all-recall trials after Bernbach's (1967) suggested "correction for guessing" has been applied to the data.

Figure 2 $\underline{d}'$ as a function of trials for Experiment II. Also plotted is $\underline{d}'$ as corrected by Bernbach's formula with (a) a constant guessing rate and (b) a trial-dependent, changing guessing rate derived from the confidence rating data. For purposes of comparison, the uncorrected $\underline{d}'$ for the group receiving all-recall trials in Experiment I is also shown.

Figure 3 The reciprocal of the probability correct, conditionalized on the confidence rating given by $\underline{S}$, as a function of confidence rating (Experiment II).

Figure 4 Cumulative per cent frequency of use of different confidence ratings, with trials as the parameter (Experiment II).

Figure 5 $\underline{d}'$ as a function of trials for the recall and recognition groups of Experiment III. Also plotted is $\underline{d}'$ as a function of trials after Bernbach's suggested "correction for guessing" has been applied to recall data.

Figure 6 Forced-choice d' for the recall group of Experiments I, II and III and standard ROC d' for the recognition groups of Experiments I and III.

Figure 7 Proportion of items called "correct" as a function of actual proportion of correct items (recall conditions from all experiments). Individual points are for separate trials.

Figure 1

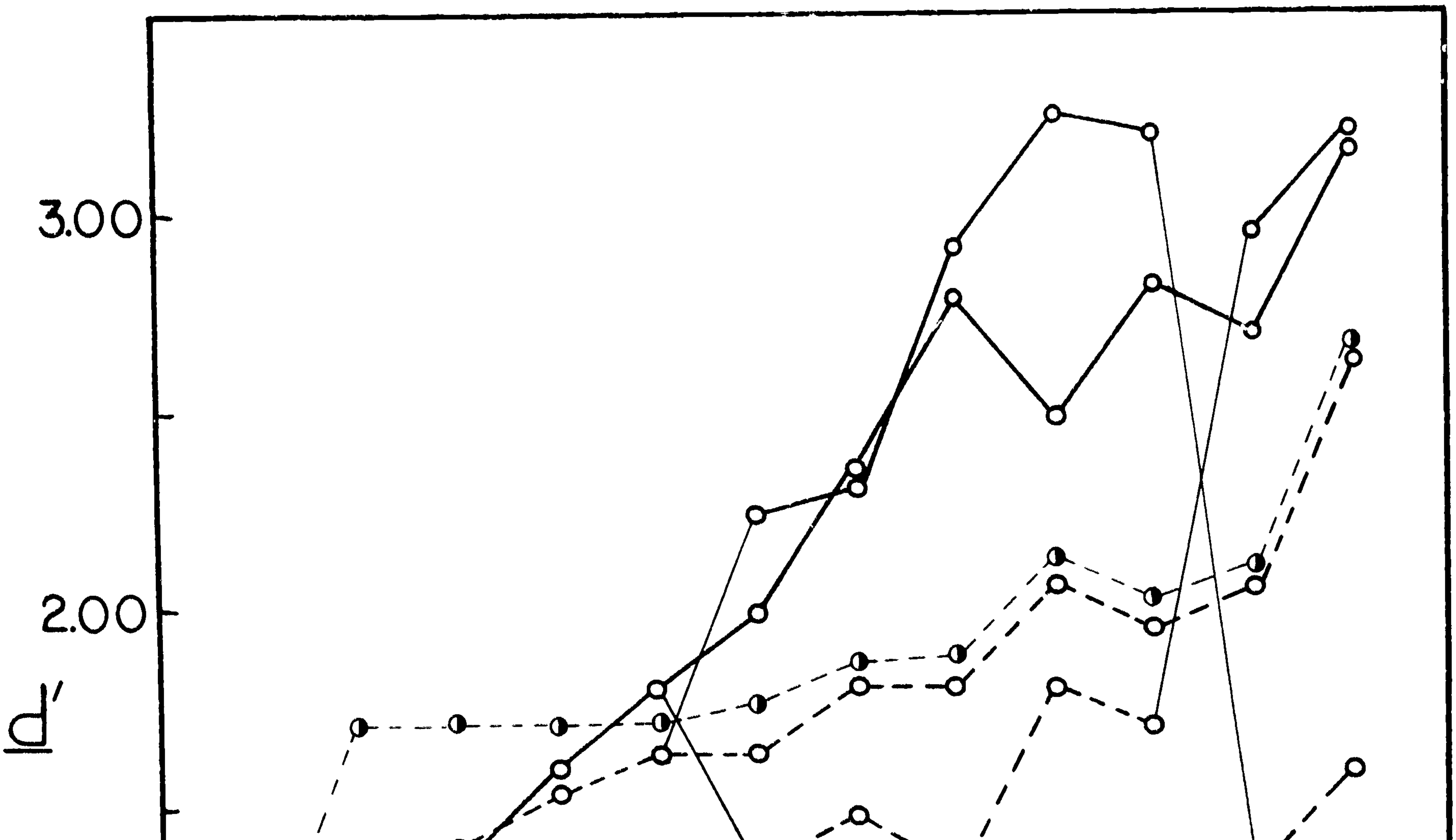

3.00
2.00
1.00
|d'
RECOGNITION
RECALL
"CORRECTED" RECALL (g = 1/N)
1
2
3
4
5
6
7
8
9
10
11
12
TRIALS

Figure 2

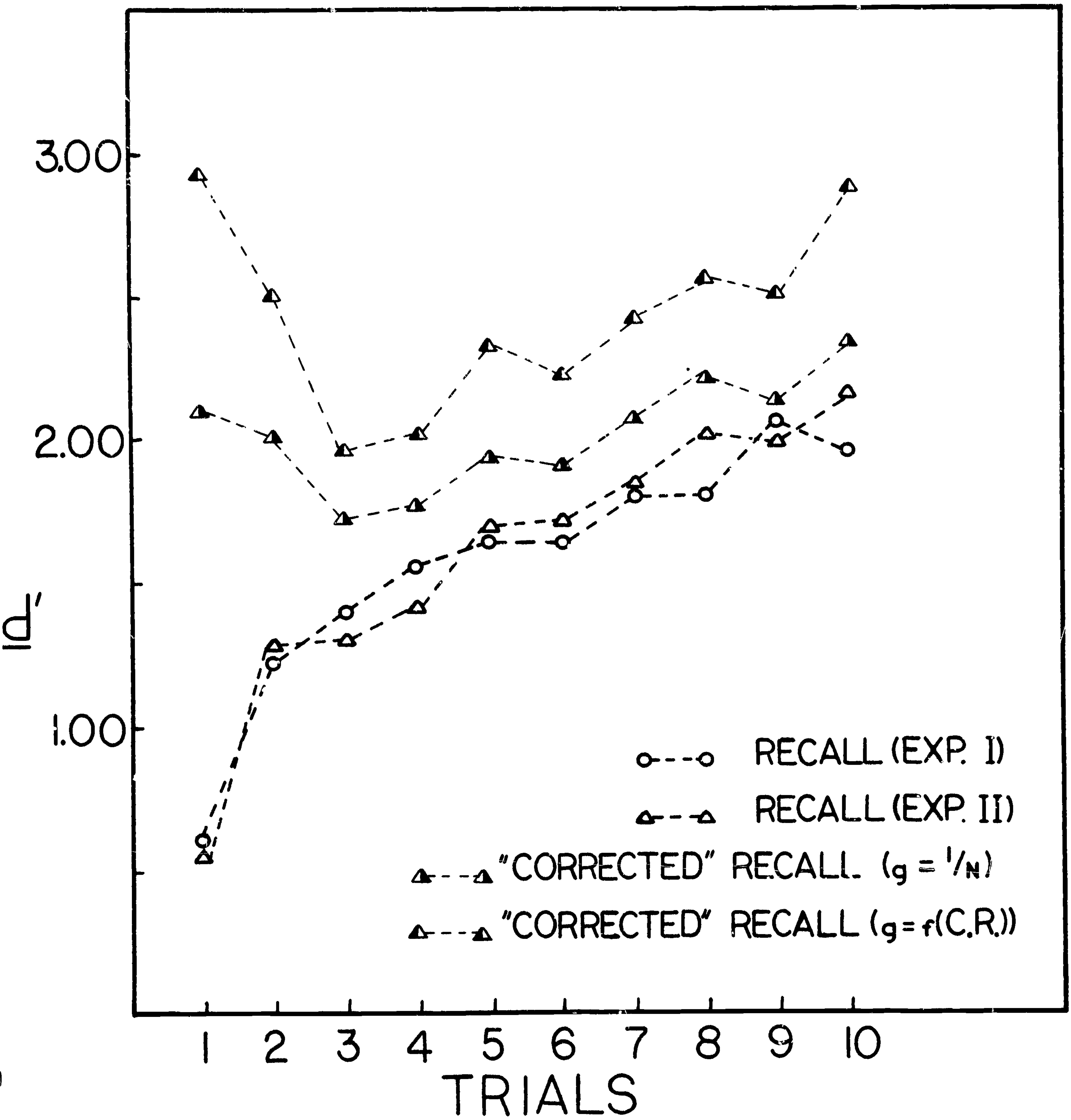
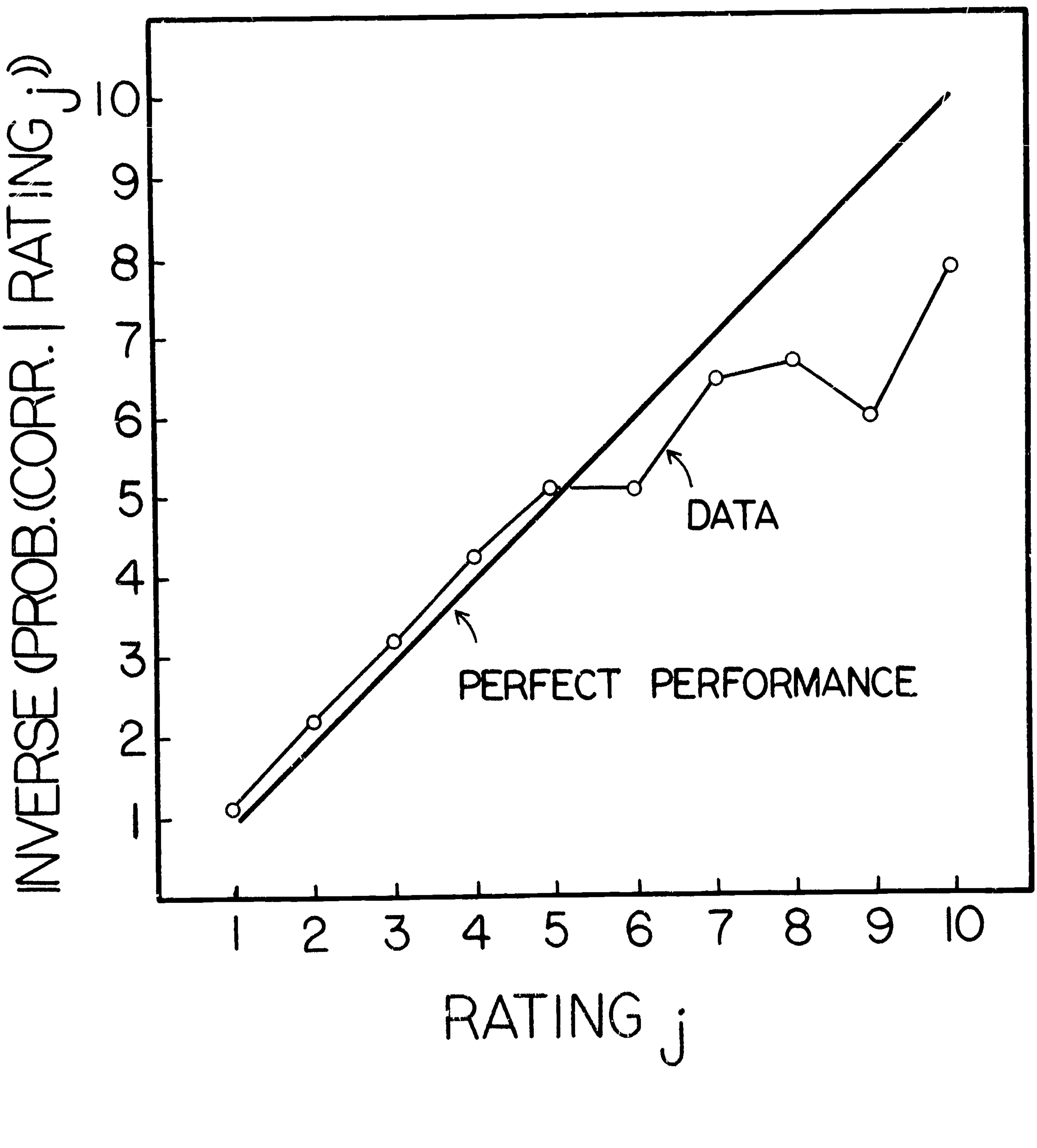
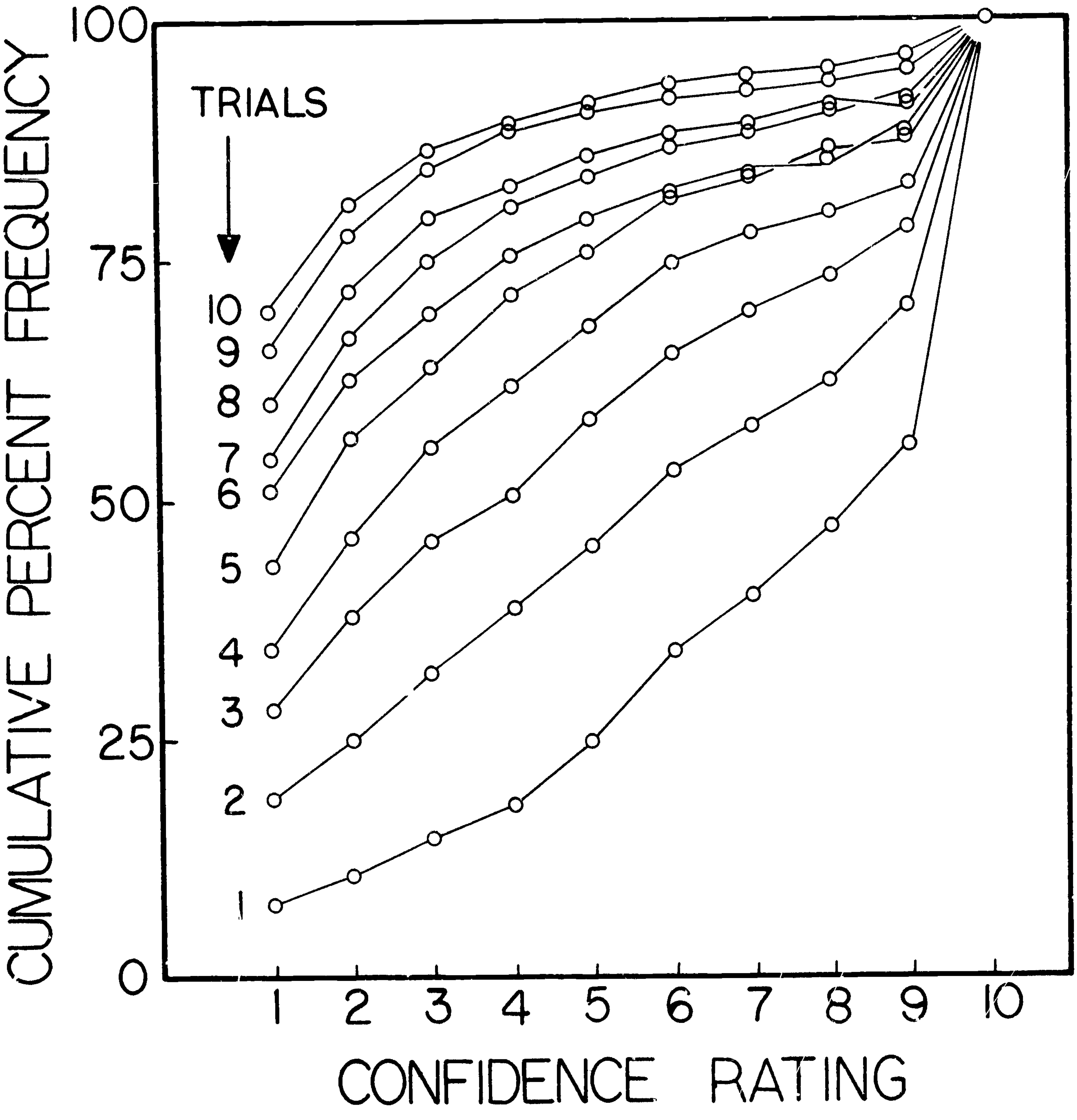

3.00
2.00
1.00
d'
RECALL (EXP. I)
RECALL (EXP. II)
"CORRECTED" RECALL (g = 1/N)
"CORRECTED" RECALL (g = f(C.R.))
1
2
3
4
5
6
7
8
9
10
TRIALS

Figure 3



INVERSE (PROB. (CORR. | RATING j))
1
2
3
4
5
6
7
8
9
10
DATA
PERFECT PERFORMANCE
1
2
3
4
5
6
7
8
9
10
RATING j

Figure 4



TRIALS
10
9
8
7
6
5
4
3
2
1
100
75
50
25
0
CUMULATIVE PERCENT FREQUENCY
1 2 3 4 5 6 7 8 9 10
CONFIDENCE RATING

Figure 5

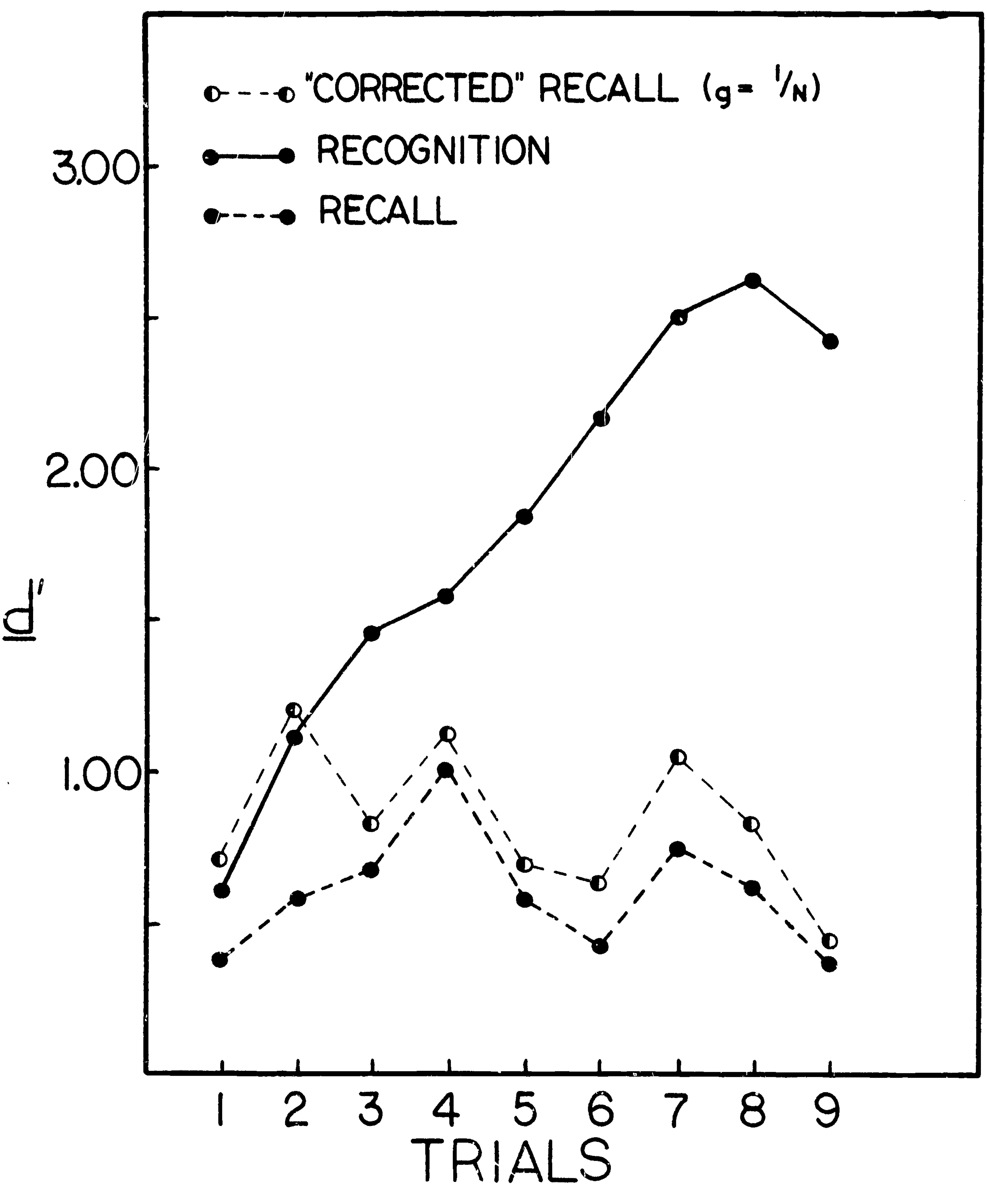
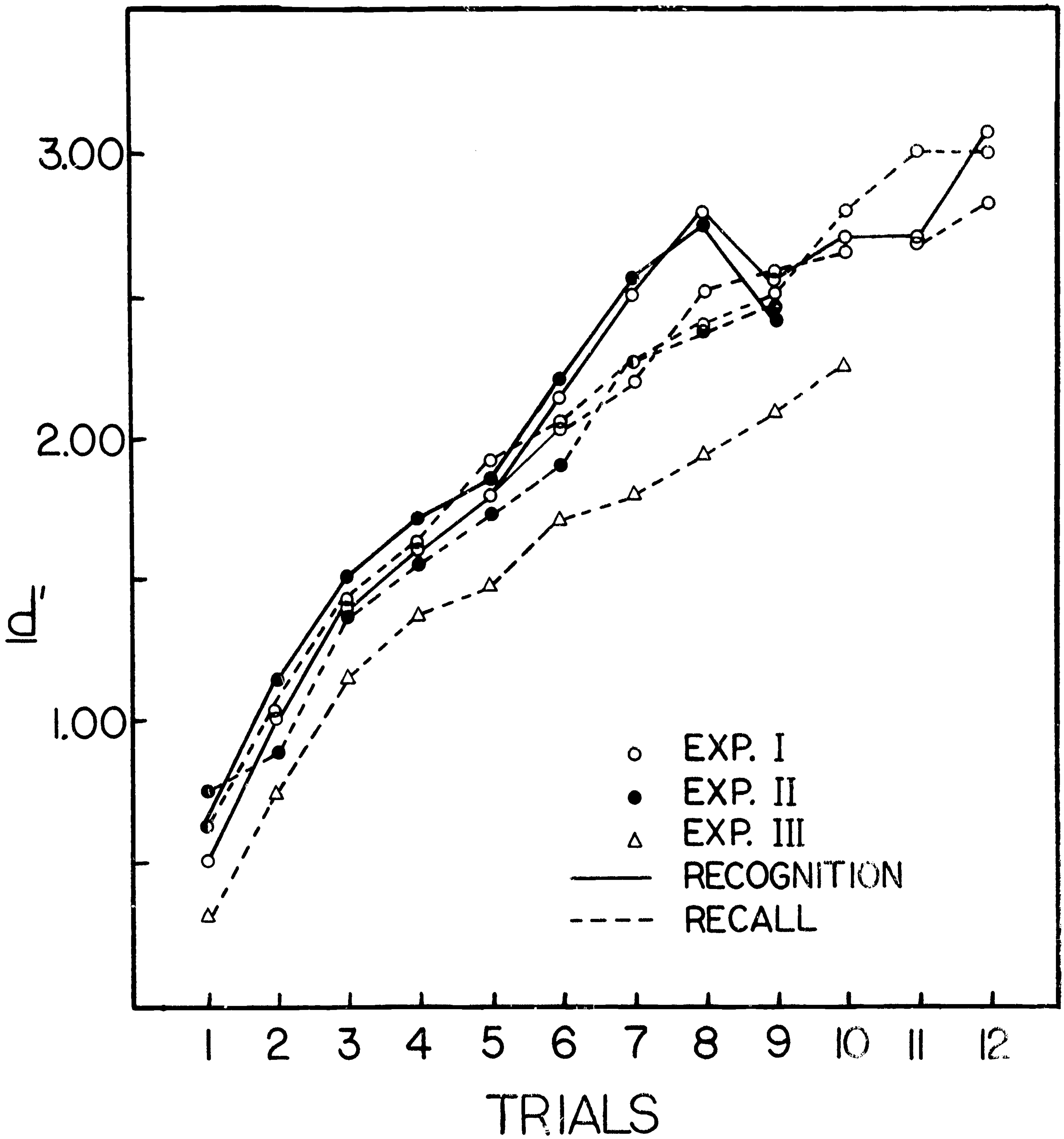

"CORRECTED" RECALL (g= 1/N)
RECOGNITION
RECALL
3.00
2.00
1.00
d'
1
2
3
4
5
6
7
8
9
TRIALS

Figure 6


3.00
2.00
1.00
d'
EXP. I
EXP. II
EXP. III
RECOGNITION
RECALL
1
2
3
4
5
6
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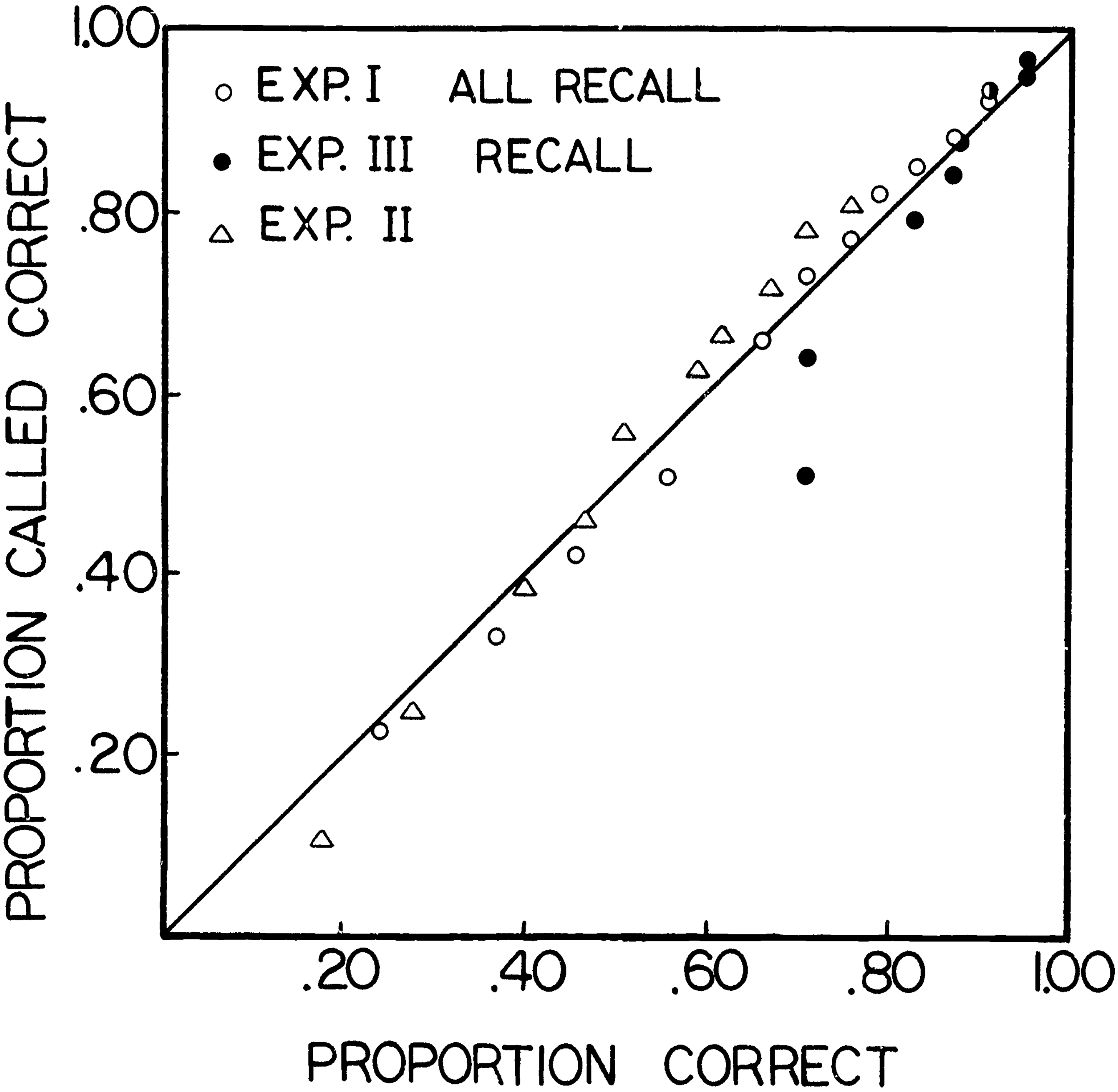
8
9
10
11
12
TRIALS

Figure 7



o EXP. I ALL RECALL
• EXP. III RECALL
△ EXP. II
PROPORTION CALLED CORRECT
1.00
.80
.60
.40
.20
.20
.40
.60
.80
1.00
PROPORTION CORRECT