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Evaluation of a neonatal hyperalimentation microcomputer program

Angelier, Daniel Michael, M.S.
The University of Arizona, 1988
EVALUATION
OF A
NEONATAL HYPERALIMENTATION
MICROCOMPUTER PROGRAM
by
Daniel Michael Angelier

A Thesis Submitted to the Faculty of the
DEPARTMENT OF PHARMACY PRACTICE
In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE
IN PHARMACY PRACTICE
In the Graduate College
THE UNIVERSITY OF ARIZONA
1988
STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

William F. McGhan
Professor, College of Pharmacy

Date
ACKNOWLEDGMENTS

This project was the result of the cumulative efforts of a number of people to whom I wish to express my appreciation. Most closely involved were the members of my thesis committee, particularly Dr. William McGhan, who spent long hours and considerable effort in consulting on this project. Without his continued support and encouragement this project would not have been possible. I also wish to thank Vic Elsberry, whose assistance in developing the computer program for neonatal hyperalimentation was invaluable.

I also wish to thank the officers of the Medical Service Corps, United States Navy, whose belief in and support of advanced education and career-long dedication to improving professional skills has remained a source of motivation and encouragement.

I also wish to express my appreciation to the members of my family. My parents were extremely influential in my early education by instilling a desire to learn and later by supporting me without reservation in any field I chose to apply myself.

For
Susan

Most of all to my loving wife and best friend, Susan, is owed my sincerest appreciation for her active support and fortitude devoted to the completion of this project. I merit my career success and happiness in life to the loyalty, faithfulness, bright sparkle, enthusiasm and love she brought to our marriage.
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Abstract

A neonatal hyperalimentation microcomputer program was designed to generate labels, and calculate mixing instructions. Artificial intelligence techniques including, interviewing experts and an inference algorithm, were employed to provide decision support in identifying clinically inappropriate orders. Development cost was $10,000. The program was alpha phase tested comparing pharmacists and technicians performance.

Task time was high and prone to human mathematical error for pharmacists and technicians using an electric typewriter and calculator. All subjects performed poorly with low confidence in manually determining inappropriate orders, although pharmacists scored slightly higher.

Task time was decreased 17 minutes with no errors using the program. Appropriateness, confidence and composite performance were vastly improved with decision support. Pharmacists composite performance was slightly higher.
CHAPTER 1

INTRODUCTION

Pharmacy like other professions is being inextricably caught up in the information communication era, ultimately relying on the utility of computer technology applications to assist professional productivity. The fundamental change in the nature of the profession from the one-man skilled dispensing pharmacognocist to drug information expert and drug use control systems manager underscore the transformation of the professional in the information age. To date the use of computers in hospital pharmacy practice have been largely limited to vendor-supplied low level application systems supporting distributive pharmacy tasks. Only recently have pharmacists sought custom designed microcomputer applications to assist drug therapy monitoring and high level clinical decision-making.

The American Society of Hospital Pharmacists has identified the three prominent components of pharmaceutical services as: 1) the procurement, distribution and control of all pharmaceuticals used within the facility; 2) the evaluation and dissemination of comprehensive information about drugs and their use to the institution's staff and
patients; 3) the monitoring and assurance of the quality of drug use. The evolution of each component of professional services has stimulated increased demands for timely and accurate information systems. While the technical skilled art of compounding has been de-emphasized, other factors such as complex dispensing systems, immense inventory control, increased governmental regulations, record keeping and multiple fiscal billing requirements have created the need for large scale data-base information systems to assist these labor intensive manual systems. "Pharmacists spent more time in the preparation of medicines for dispensing thirty years ago when dosage forms were compounded by the pharmacist than today when almost all prescriptions are filled with commercially prepared products....During this time the number of drugs has dramatically increased. ... The amount of information that a pharmacist has been required to learn, retain and use has increased more rapidly than the number of drugs." (Browning 1983) The latter day components of pharmacy services, monitoring patient drug therapy for clinical appropriateness and drug information intervention, have evolved as major non-distributive pharmacy tasks requiring specialized knowledge and expertise to effect clinical decision-making. The future of pharmacy productivity lies in knowledge engineering and information systems planning for automated control and efficiency of
both distributive and non-distributive task requirements of drug use process. (Joseph, 1982)

Drug Use Control: Evolution of Distributive and  

Non-Distributive Professional Tasks  
The primary responsibility of the hospital pharmacist is the facilitation and control of medication use throughout the hospital. Drug use control, a term coined by Dr. Brodie in the 1960's, is defined as the sum total of knowledge, understanding, judgment, procedures, skills, control and ethics that ensure optimal safety in the use of medication (Brodie, 1965). As defined by Brodie, total drug use control within a hospital results when the pharmacy department directly coordinates both distributive and non-distributive drug-use functions:

Figure 1. Drug Use Control

<table>
<thead>
<tr>
<th>Distributive</th>
<th>Non-Distributive</th>
</tr>
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<tbody>
<tr>
<td>- purchasing</td>
<td>- administering</td>
</tr>
<tr>
<td>- receiving</td>
<td>- prescribing</td>
</tr>
<tr>
<td>- storing</td>
<td>- monitoring</td>
</tr>
<tr>
<td>- inventory control</td>
<td>- information</td>
</tr>
<tr>
<td>- transcribing orders</td>
<td>- teaching</td>
</tr>
<tr>
<td>- preparation (compounding)</td>
<td>- research</td>
</tr>
<tr>
<td>- labeling</td>
<td></td>
</tr>
<tr>
<td>- dispensing</td>
<td></td>
</tr>
<tr>
<td>- transporting</td>
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</table>
Distributive Tasks

Distribution functions are an integral element of drug use control. In the 1970's the unit dose system of drug distribution replaced conventional floor stock and individual prescription systems as the accepted standard of practice (Tousignaut, 1977). Under this system pharmacy dispensed limited quantities of medication at regular time intervals for each patient's unique regimen. The system decreased excessive inventory, freed nursing personnel from much of the preparation and dispensing labor associated with previous floor stock drug administration, decreased waste and pilferage and increased accountability for doses dispensed. The growth and expanding use of parenteral drug therapy, particularly the complexity of intravenous hyperalimentation, supplied the impetus for pharmacy intravenous admixture services. In the mid-1960's pharmacists recognized their qualifications and responsibility to formulate and compound intravenous solutions just as they had compounded ointments, capsules, ophthalmics, etc.. Pharmacists seem well trained in calculating doses, product concentrations, formulation volumes of additives required and rates of administration. Their background in chemistry and pharmaceutics allowed for the expertise to examine prescribed admixtures for potential incompatibilities. Centralized admixture services prepare intravenous solutions for laminar air flow hoods, inspect
finished products for particular matter, and maintain quality assurance activities. The Joint Commission of Accreditation of Hospitals has now adopted unit dose and pharmacy intravenous admixture services as preferred standards of care (Smith and Brown, 1979).

Distribution Systems Manager

The advent of unit dose and intravenous admixture programs greatly expanded manual labor intensive distributive tasks. Hospital pharmacy departments were compelled to augment their staffs with several levels of personnel from secretaries and clerks to technicians, staff pharmacists, supervisors and directors. Support personnel became an integral part of distribution systems, freeing pharmacists from mundane repetitive tasks. Many of the distributive task functions could be delegated to support technicians as long as limitations, supervision and quality control measures were enforced to assure accuracy and patient safety (Barker, 1969). The staff pharmacist evolved from the one-man skilled compounder to a distribution systems manager (Smith and Knapp, 1976).

Non-Distributive Tasks

The new distribution systems actually gave impetus to pharmacists' emerging non-distributive clinical role in effecting drug use control. Pharmacists began to maintain individual patient medication distribution records later
named medication patient profiles (Barker, 1969), of doses ordered and dispensed. The record documented the dispensing process and served as a distribution tool to schedule future unit dose and intravenous preparation and delivery requirements. The medication record, originally a distribution tool, became an information tool allowing pharmacists an opportunity to exert their knowledge and expertise to influence the selection and prescribing aspects of the drug use process.

Reviewing Orders for Clinical Appropriateness

In many unit dose and intravenous additive programs, pharmacists were provided with direct copies of the physician's original orders and maintained pharmacy-based drug medication profiles. This process allowed pharmacists to correct deficiencies in interpretation and transcription of physicians' orders resulting from the lack of previous review by a pharmacist (Black and Tester, 1964). These orders were reviewed with respect to current drug therapy, patient's allergies and current disease states. An apparently inappropriate or questionable order could be delayed by the pharmacist who could further investigate patient-specific clinical laboratory data and, if needed, consult with the prescriber with drug information intervention to effect optimal therapy. This process served as a check on order safety (Davis and Cohen, 1981). This "reviewing of orders for appropriateness" became a major
non-distributive pharmacy task requirement and was ultimately adopted as a standard of pharmacy care by The Joint Commission of Accreditation of Hospitals. The following excerpts are from The American Society of Hospital Pharmacy's "Minimum Standards for Pharmacies in Institutions":

"Standard V: Assuring Rational Drug Therapy

The most important aspect of pharmaceutical services is that of maximizing rational drug use. ...Sufficient patient information must be collected and maintained by the pharmacist to insure meaningful and effective participation in the patient care process. ...Appropriate clinical information about patients must be available and accessible to the pharmacist for use in his/her daily practice activities. ...All physicians' medication orders (except in emergency situations) must be reviewed for appropriateness by the pharmacist prior to dispensing the first dose. Any questions regarding the appropriateness of the order should be resolved with the prescriber at this time and a written notation of these discussions made in the chart or copy of the physician's order. ...The pharmacist, in addition to supplying specific drug information, must be able to furnish objective evaluations of drug literature and to provide informed opinion on drug related matters."

(Smith and Brown, 1982)

Non-Distributive Specialized Skills and Training

Non-distributive clinical pharmacy services have evolved and expanded over the past 30 years, demanding specialized knowledge and expertise to facilitate drug use control. The drug information specialist was the first to emerge (Hutchinson and Burkholder, 1971, McLeod, 1976). Just as the complexities of medical practice required physicians to specialize, pharmacists are now practicing in
specialized positions such as adult medicine, pediatrics, psychiatry, surgery, intensive care units, ambulatory care, family medicine, pharmacokinetic services and as part of formal hyperalimentation teams (McLeod, 1976). Pharmacy schools have responded to these new roles by developing programs which teach drug-related diagnoses and treatment, drug product selection and evaluation, and drug therapy monitoring techniques. Specialized post graduate education programs allow for specialized residencies and fellowships in a variety of specialties. The pharmacy professional is becoming increasingly identified with specialties and specialty certification (McLeod, 1976).

Expanding Professional Tasks and Shrinking Resources

Hospital pharmacy professional tasks requirements have continued to evolve and expand, commanding increasing time, labor and specialized professional expertise. Hospital pharmacies have been compelled to augment their staff with additional technicians, staff and specialized clinical pharmacists to meet the increased demands of distributive and non-distributive services and programs.

Professional task requirements have increased, while in recent years hospital reimbursement charges such as diagnostic related groups and fixed-fee capita have forced administrators to be far more sensitive to case mix profitability, and services provided. The impact and
benefits of departmental programs must be critically weighed in light of resource utilization, personnel productivity and the necessity for cost control measures. Prospective payment and per capita reimbursement systems have placed tighter constraints on personnel and financial resource allocations. These same hospital economic forces have prompted administrators to look to pharmacy to monitor patient drug therapy and prospectively influence physician prescribing to control costs and promote safe optimal drug therapy. Changes in hospital revenue structures have further expanded non-distributive functions while placing greater limitations on personnel and resources. (Oddis, 1984)

Adoption of Computer Technology

Complex distribution systems, financial billings systems, governmental regulations, and expanding professional tasks demands have created the need for automated computer assisted information systems. The first reported computer application to assist pharmacy professional tasks appeared in the literature in 1969. The adoption of computer technology, micro, mini and mainframe hardware, supporting a variety of software applications have continued to grow at an exponential rate. (Browning, 1969) Despite the exponential growth and diffusion of computer technology in pharmacy, the current utility of computer
applications in hospital pharmacy practice to automate both distributive and non-distributive professional tasks in its infancy (Lockwood and Bauman 1984).

Low Level Applications

The potential utility of computer technology to provide automated monitoring and efficiency to pharmacy professional tasks is immense. However, to date, the use of computers in hospital pharmacy has been largely limited to vendor supplied systems performing low level data processing and data base management of patient profiles, laboratory data access, inventory control, label generation, unit dose cart filling lists and automated billing systems. Marvin Chamberlain, in discussing the computerized support of clinical pharmacy services, observed "These low level applications have largely supported distributive pharmacy tasks and only indirectly supported non-distributive pharmacy tasks, by freeing personnel from repetitive clerical tasks, and by allowing pharmacists more efficient access to patient care information" (Trudeau, 1982).

Limited Support for Reviewing Orders for Appropriateness

Vendor-supplied systems have provided limited support to reviewing orders for appropriateness and drug information problem solving and intervention. Some vendors include automatic allergy and drug interaction programs as
part of their pharmacy system. These programs do not
directly make decisions about patient therapy, but serve as
an automatic check for potentially inappropriate therapy.
Thus, the first step drug therapy problem solving and
information intervention, that of identifying a potentially
inappropriate order, is performed automatically. The
process of evaluating the severity or in some cases the
benefit of the drug interaction, and exploring the need for
alternative treatment, is left to the professional (Bouchard

Drug allergy, drug lab and drug interactions are but
a few of the reasons why therapy may be inappropriate.
Therapy may be suboptimal due to a variety of reasons:

a. The dosing regimen may be potentially toxic or
subtherapeutic;

b. The dosage form or route of administration may
be incorrect;

c. The drug may be incompatible with other agents
or diagnostic tests;

d. The choice of agent for a specific therapeutic
goal may be less effective, potentially more toxic, or even
unnecessary must consider the firmness of the diagnosis);

e. The selected therapy may be less cost effective
than therapeutically comparable agents; or
f. The therapy does not conform to a hospital-approved protocol, designed for safety, cost or labor saving, staff or patient convenience, etc.

Inappropriate orders are not always clear life threatening contraindications. The amount of new medical information doubles every 17 years (Madden, 1977, Joseph, 1982). New information ultimately evolves from controversial to accepted and established therapy. Often the pharmacist may need to intervene in this process, either by individual drug information consultation with a prescriber or through formal committee decision, making such as the hospital formulary committee. Pharmacists are expected to facilitate and promote the guidelines and treatment protocols established by drug utilization review, antibiotic utilization review, cardio-pulmonary resuscitation, pharmacokinetic and hyperalimentation committees. Administration and the medical staff expect pharmacy to apply their knowledge and expertise through the intervention process to promote patient safety and cost effective drug therapy (Penna and Knapp, 1986). Thus, inappropriate therapy may simply entail recognizing and promoting a simpler regimen, non-formulary substitute or local protocol for staff labor savings, safety or patient convenience.
Proprietary Syndrome

Traditional vendor-supplied pharmacy systems have not, and very likely for the immediate future, will not support clinical review of drug order appropriateness and clinical pharmacy decision making tasks. The problem is due to what some experts refer to as the "proprietary syndrome" (Pantages, 1986). The failure of large scale commercial information systems to meet the unique decision making needs of high level professionals is due to the economic and historical trust of large scale commercial information systems vendors:

a. Information systems have historically grown out of a tradition of supporting low level repetitive manual tasks such as automated accounting and billing.

b. Vendors would prefer to supply static, canned, fixed reports than the more complex and expensive utility of a query system.

c. Vendors cannot economically provide individual users with a programmable interactive system or a variety of individual user application development or software tools.

d. Vendors would prefer to offer dumb terminals over the complexities of user-owned microcomputers or vendor-supplied mainframe linkage to avoid the complexities of a multi-contractual arrangement of linking to a local area network system provided by another vendor.
Vendors and Commercial Support Systems

The above problems have limited the utility of vendor-supplied medical information systems for high level unique professional decision support applications. Most vendors would avoid medical decision support programs because:

1. The development of an expert system is a time consuming and expensive process involving problem analysis and a program development coordinator, problem data research, interviewing experts, complicated programming and debugging stages.

2. The knowledge base and algorithms are controversial, must be individualized to suit each potential client, and change rapidly with new information. Thus, the product has a short life cycle, a high maintenance cost and limited generic market appeal.

3. The expense of a custom medical expert system development venture often has a low return on investment potential because of the limited medical market target of the specialty program.

4. Medical expert systems potentially incur medico-legal liability for the commercial software vendor.

Individual Designed Microcomputer Applications
The emergence of low cost powerful personal computers and the growing availability of a variety of application development software has allowed pharmacists to use these tools to support pharmacy functions not supported by the typical vendor-supplied system. Word processing programs are used for newsletters, correspondence and label generation. Database and spreadsheets are used to analyze workload statistics, departmental budgets and rug utilization review studies. Pharmacists have also widely utilized the microcomputer to develop their own custom designed pharmacokinetic programs to assist in individualizing patient dosing regimens. (Chamberlain, 1982).

Microcomputer Applications in Hyperalimentation Save Time and Decrease Mechanical/Mathematical Errors

Recently pharmacy microcomputers have been employed to asset pharmacists in the support of clinical nutrition assessment and the preparation of hyperalimentation. The growth and technological advances in hyperalimentation therapy, particularly neonatal hyperalimentation, account for a considerable increase in pharmacy workload, compared to other forms of intravenous therapy. One workload study indicated that the average antibiotic admixture piggy-back preparation time accounted for 3.7 minutes, while each
bottle of adult hyperalimentation required 13.4 minutes, and neonatal hyperalimentation accounted for 49 minutes of pharmacy and technician time (Ryan et al, 1986). Neonatal hyperalimentation can consist of up to 17 ingredients. Typically solutions are custom ordered and change daily. The additive quantities and volume to be infused over 24 hours by the prescribing physician must be increased by an overfill volume to provide sufficient volume to fill pump cassettes and intravenous lines. The volume of each additive to be added from concentrated stock solution vials must be calculated. The sum of the additives must be calculated and subtracted from the final actual volume to calculate the volume of sterile water to be added to the final product. In addition the pharmacist must calculate a calcium phosphate product ratio to ensure that the prescribed solution will not precipitate. The entire calculation procedure requires over 60 mathematical operations. If a hand-held calculator is employed the user must enter 128 numeric and operation entries. The labeling, calculation and formulation of neonatal hyperalimentation is a time consuming distribution task with a high potential for transcription and mathematical errors (Thomas, 1987).

The Richland Memorial Hospital employed a number of standardized ordering protocols, pharmacy calculation worksheets, the aid of calculators and preprinted formatted
labels to decrease the number of medication errors and task time associated with the preparation of neonatal hyperalimentation. In 1986 the departments of pharmacy and coordinated a personal computer program to calculate mixing instructions and automated label preparation. The department realized a reported labor savings of nine minutes for each neonatal hyperalimentation solution prepared. Based on their workload statistics, they freed a 0.4 full time pharmacist equivalent position per year (Thomas, 1986).

Need for Computer Support: Human Error

The propensity of hospital staff personnel to make errors in the preparation of pediatric doses has demonstrated that in order of propensity nurses, physicians and pharmacists are all prone to mathematical errors (Koren et al, 1983). Koren's study indicated that experienced professionals were as likely as inexperienced professionals to commit errors. Most of the errors committed were attributed to human mundane errors of transcription or more alarmingly resulted in a ten-fold overdose or underdose due to misplacement of the decimal point. It was surmised that pharmacists while guilty of committing errors, scored a lower error rate due to their training and experience. It might be expected that computer assisted calculation of neonatal hyperalimentation would result in decreased mathematical errors, as reported by the Richland Memorial
Hospital Experience, although the impact was not quantitatively compared with traditional standard methods by a rigorous study.

Need for Computer Assisted Decision Support: Failure to Identify Inappropriate Orders

Medication errors have been well documented by a number of hospital surveys and texts (Davis and Cohen, 1981). Many errors are caused by physicians writing unreadable orders, the misinterpretation of physician orders and mathematical errors. Failure to identify an inappropriate order can result in iatrogenic disease, patient suffering, increased length of stay and hospital costs, malpractice litigation and death. The authors cite inexperience and failure to identify potentially inappropriate therapy as a common cause of patient medication errors.

Perlstein, et al, tested 95 registered nurses' ability to correctly compute drug dose preparation volumes. Nurses had an 8% error rate while physicians missed one problem in 26, or 4% and pharmacists missed a lesser amount. Fifty-six percent (56%) of the wrong doses would have resulted in a dose ten times greater or less than the ordered dose. This study also tested nurses and physicians ability to correctly identify without the use of written references if the dose was appropriate for a specific
neonate. The nurses were unsure in their determination 30.3% of the time and actually incorrect 28.8% of the time. Experienced neonatologists were unsure 7.2% of the time and incorrect in 19% of the time in their determination of order appropriateness. Pharmacists were not included in the appropriateness phase of the study.

Pharmacy managers are faced with the often untenable requisite to insure reliable fail-safe monitoring and detection of inappropriate drug therapy orders. Neonatal pediatric therapy is highly specialized area of pharmacy practice. Specialized pharmacists' roles in neonatal hyperalimentation teams, including formalized committee membership, assisting in ongoing research, monitoring therapy, rounding with neonatology teams and providing consultation, have been well established (Kerner, 1983, and Cerra, 1984). Justifying and maintaining a specially trained clinical pharmacy position to provide sophisticated neonatal hyperalimentation pharmacy services is both expensive and may become a lesser priority compared to other hospital needs for clinical services. Given the economic pressures to cut back on staff and trim services, only a few hospital pharmacy departments can afford a specialized pharmacist to provide neonatal hyperalimentation consultation and daily monitoring in the patient care area.
The centralized intravenous admixture pharmacist has traditionally assured the timely and accurate preparation of neonatal hyperalimentation solutions. While his primary responsibility has been distribution, he is often the sole staff member responsible for reviewing neonatal order items for appropriateness. Neonatal hyperalimentation is a highly complex and specialized field requiring training and experience to develop competent expertise. Determining order item appropriateness can range in complexity from recognizing an obvious, ridiculously high overdose to reviewing the patient's lab data, weight, age and clinical parameters. Can we expect the average registered pharmacist with general hospital intravenous admixture experience to recognize an obvious overdose of potassium, much less a contraindication to fat emulsion due to laboratory abnormalities in a neonate. Some pharmacies are staffed with a daytime centralized pharmacist who is experienced and competent at these tasks. However, the problem of weekend and emergency night preparation of solutions challenges the reliability of pharmacy departments to assure item appropriateness review.

Expertise in recognizing order item appropriateness depends on the frailty of human knowledge, memory and the reliability of personal clinical skills. When new, less experienced staff members are oriented and trained to assume responsibilities, their expertise is additionally subject to
the limitations of human knowledge transfer as the novice pursues independent study and learns directly from an accomplished expert.

PROBLEM

The current level of microcomputer technology hardware and software is capable for supporting useful decision-support systems to provide consultation systems for a specific professional purpose (Williamson, 1987). These development tools can be used to support traditional computer applications such as automated mixing instructions and label generation for neonatal hyperalimentation as well as provide the user with information to assist in identifying inappropriate orders.

Decision-support systems are often hampered by the amount of information required by the user to input. For example, if a general wishes to combat strategy consultation in a nuclear war that can be over in minutes and the program requires the user two hours to enter the input information, the program becomes useless.

The usefulness of the system also depends on the importance the user attaches to the consultation information. For example, not all pharmacists, or technicians, agree with the extent of pharmacy's
responsibility to review order items for appropriateness. James Slagle and Michael Gaynor at the Navy Center for Applied Research in Artificial Intelligence, 1986, stated this problem in the following axiom, "User utility is inversely proportional to input time required of the user, and directly proportional to the user perceived importance of the output." The program associated with this project was designed to assist users in identifying order appropriateness based on entering a minimal amount of information, i.e., the order, current date, name of patient, date of birth, and patient weight. A much more sophisticated clinical report could be produced if users were willing to enter 12 to 35 additional input fields for patient parameters and lab values. Additional input fields would provide a more sophisticated report but double the input time task.

Data processing departments and administration have traditionally viewed custom designed departmental microcomputer programs as expensive extravagances, serving a limited number of users, further fragmenting data processing resources and a questionable allocation of funds. Current literature suggests that a custom designed microcomputer application could positively impact both distributive and non-distributive pharmacy task goals. Pharmacy credibility in effecting total drug use control is
increasingly limited by stringent personnel and resource limitations. Therefore, the problem formally stated is:

Problem Statement

There is a need to evaluate the effectiveness and the development cost of a custom designed microcomputer application, designed to assist pharmacists and technicians in performing distributive and non-distributive neonatal hyperalimentation pharmacy tasks, to the traditional manual pharmacy method.

Objectives

Objective 1. Given the availability of powerful low cost microcomputer hardware and application development tools, the first phase of this project was to develop a customized microcomputer application to support both distributive and non-distributive pharmacy tasks associated with neonatal hyperalimentation. The program was specifically designed to decrease the task time associated with label generation and calculating mixing instruction, to reduce the number of mathematical errors and to simultaneously assist users in correctly identifying order item appropriateness.

Objective 2. The major objective of the study was to evaluate the utility of a custom designed microcomputer application by performing a cost effective evaluation to
identify program development costs and to compare pharmacy utility impact measures between computer assisted and traditional manual methods by level of subject experience, i.e., pharmacist versus technician user.

Objective 3. The utility of a computer application is derived from having the computer automatically calculate and generate several reports from a single input procedure mimicking an original manual task (Joseph, 1982). Therefore, the labor required to type a label becomes the input procedure to the computer program. An ideally efficient program would be capable of supplying labels, mixing instructions and a clinical report all from a single efficient input procedure. Therefore, another objective of this study was to compare pharmacy task times for label generation, calculation time and total task time by method of preparation and by level of experience.

Objective 4. Mathematical errors appear to be largely due to human error more so than level of experience. This study objective sought to quantify the impact of the computer program on the number of errors compared to manual methods by level of experience.

Objective 5. Certainly the training and experience received by registered pharmacists compared to technicians would be expected to result in superior skills in identifying order
items for appropriateness. This study objective sought to quantify the impact of computer on subjects' ability to correctly identify order items for appropriateness, compared to traditional methods by level of subject experience.

Objective 6. Registered pharmacists would be expected to have a higher confidence in determining order items for appropriateness compared to technicians. User confidence in the consultation output from an expert system is dependent on the transparency of the program output (Williamson, 1976). The user will be more confident in the output information if the program is explicit in explaining its reasoning process to the user. This study objective thus sought to quantify the impact of computer assisted determination of appropriateness versus manual determination on user confidence by level of experience.

The relationship of pharmacy task performance in identifying order time appropriateness is related to the composite accuracy and confidence of the user. The least desirable performance is exemplified by the user who is repeatedly highly confident and highly inaccurate, while the ideal composite performance would comprise the user who is consistently highly confident and accurate. This study objective thus sought to quantify the impact on user
composite performance by level of experience of computer assisted determination of appropriateness versus manual determination of appropriateness.

Objective 7. Qualifying and comparing pharmacist and technician perception of the importance of pharmacy's responsibility to review order items for appropriateness.

Objective 8. Quantifying and comparing pharmacist and technician willingness to enter additional input data to obtain a more sophisticated clinical report.

Objective 9. This study objective sought to quantify the relationship between the perceived importance of pharmacy's responsibility to review order items for appropriateness and willingness to enter additional input data. If Slagle and Gaynor's axiom is correct the users who attach a high importance to reviewing order items for appropriateness would also be more willing to enter additional input data. To better understand the utility of pharmacy based expert consultation systems for future planning the study sought to confirm the relationship between these constructs.
PROJECT PLAN

The formal problem statement and aforementioned objective demanded a comprehensive research project plan. The project plan consists of three phases

1. Needs Identification.
2. Microcomputer Program Development.

Phase 1: Needs Identification

The Needs Identification Phase included background research and a literature review (see Chapter 2) related to the identification of the problem, the planning of the microcomputer program intervention and the program evaluation. This phase identified distributive and non-distributive pharmacy personnel task requirements in the preparation of neonatal hyperalimentation. Traditional neonatal hyperalimentation task support was identified as formatted labels, calculation worksheet and the use of handheld calculator. Deficiencies in this process were identified as program output criteria that could potentially be improved by a computer-assisted intervention. The following diagram provides a model of the needs identification process of phase 1:
Phase 2: Microcomputer Program Development

The second phase of the project involved the microcomputer application development process. The program design and development is explained in greater detail in Chapter Three: Methodology. The development of the program, "TPN.COM", required the following steps:

1. Identifying program input and output data and human interface goals.

2. Detailed research and analysis of the problem of "identifying order item appropriateness":

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<thead>
<tr>
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<th>Output Criteria</th>
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<tbody>
<tr>
<td><em>Technicians</em></td>
<td>Manual</td>
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<td>* Errors</td>
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<td>* Intervention</td>
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Phase 1: NEEDS ASSESSMENT

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</table>
a. Interviews with experts in neonatal hyperalimentation.

b. Problem analysis.

c. Inference engine design

3. Selection of hardware.

4. Selection of programming language.

5. Programming:
   a. Problem-solving and algorithm design using top down modularity and stepwise refinement.
   b. Conversion of pseudocode to Pascal.

6. Compilation, debugging and bench testing.

The following diagram provides a diagram of the component steps in the microcomputer program development process:

**Figure 2. PHASE 2: MICROCOMPUTER PROGRAM DEVELOPMENT FLOWCHART**
Phase 3: Program Evaluation

The program evaluation was undertaken to assess the cost and output criteria of the computer-assisted intervention compared to the traditional manual method commonly used in preparing neonatal hyperalimentation.

The program evaluation phase of the Thesis Project included the following planning and execution:

1. Developing a conceptual framework for the program evaluation.
2. Adopting an evaluation methodology.
3. Methodology (See Chapter 3).
   a. Research design.
   b. Instrument development.
   c. Selection of subject.
   d. Data collection.
   e. Data analysis.
4. Results
5. Discussion and conclusions.
CONCEPTUAL FRAMEWORK

The evaluation was conceived as a context-input-process-output model. The following diagram presents a conceptual framework of the program evaluation model:

**Figure 3. CONCEPTUAL FRAMEWORK FOR THE EVALUATION MODEL**

<table>
<thead>
<tr>
<th>Input Data</th>
<th>User</th>
<th>Method</th>
<th>Output Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Order</em></td>
<td><em>Technicians</em></td>
<td><em>Manual</em></td>
<td><em>1. Cost</em></td>
</tr>
<tr>
<td><em>Lab Data</em></td>
<td><em>Pharmacists</em></td>
<td><em>Computer</em></td>
<td><em>2. Time</em></td>
</tr>
<tr>
<td><em>Patient</em></td>
<td><em>Parameters</em></td>
<td><em>Computer</em></td>
<td><em>3. Errors</em></td>
</tr>
</tbody>
</table>

The context of the study, i.e., its setting and conditioned was designed to mimic pharmacy task requirements and conditions in preparing neonatal hyperalimentation.

The input included input data and subject users. The input data was designed as pre-prepared patient information, lab values and mock physician orders. Subjects included technicians and registered pharmacists with hospital intravenous additive experience.
The process compared traditional manual and the computer-assisted intervention methods for preparing neonatal hyperalimentation.

Output criteria identified in the model were formally defined (see Definitions) and extensionalized (see Methodology).

**EVALUATION METHODOLOGY**

The evaluation methodology was adopted and modified from that described by Bootman, McGhan and Schondelmeyer as a cost effective evaluation:

"COST EFFECTIVE ANALYSIS: A program evaluation technique to provide decision makers with identification and/or quantification of comparative program costs and selected impact measures among two or more program alternatives."

(Bootman, McGhan, and Schondelmeyer, 1982)

The program evaluation technique adopted was a cost analysis technique. The program evaluation technique sought to identify development cost and quantify selected impact measures comparing pharmacist and technician performance in preparing neonatal hyperalimentation, using the traditional manual method and the computer assisted intervention. The intent of the evaluation was descriptive and not intended for comparative decision making based on some pre-set
specified outcome. Rather, the purpose of evaluation was to examine the performance output criteria of the users as a result of the use of the computer program intervention.

The study design was driven by a concern for exploratory analysis of the computer intervention by scientifically testing specific research hypotheses in a theoretical framework.

The intent of the evaluation program was to advance theoretical knowledge related to the research hypotheses and study objectives in an experimental laboratory-controlled environment, ideally removing site and subject specific confounding variables.

The research design consisted of a randomly assigned, prospective, laboratory-controlled experimental intervention model.

It would be medico-legally negligent to field test the computer intervention prematurely in an actual hospital setting. Thus, the study's aim was exploratory research and avoided problems of patient well-being by using a laboratory-controlled setting. Ideally, theoretical knowledge advanced in the laboratory will advance future practical applications in the field.
THESIS ORGANIZATION

This chapter concludes with a list of the formal hypotheses to be researched and a definition of terms. The end of this chapter formally defines terminology used throughout the study and specifically the extentionalization and measurement of the construct variables used in the study design. A review of the related literature is presented in Chapter 2. The following three chapters examine the program evaluation in its component parts: context, input, process and output criteria. In each section, methodology, results and the findings will be presented and discussed. Finally, conclusions of the study projections and recommendations will be presented.
Hypothesis

The central hypothesis tested, stated in the alternative form, was:

Central Hypothesis: A custom developed microcomputer program, designed to support distributive and non-distributive pharmacy task functions associated with neonatal hyperalimentation will demonstrate utility measures compared to traditional manual methods for both registered pharmacists and technicians.

This hypothesis will be evaluated in terms of various utility measures. Each hypothesis associated with these measures is stated in the alternative form.

Hypothesis 1. Total computer task time will be less than total manual task time.

Hypothesis 2. Total computer task time for pharmacists will be less than total computer task time for technicians.

Hypothesis 3. Total computer task time will be less than manual label time.

Hypothesis 4. Computer mathematical errors will be less than manual mathematical errors.

Hypothesis 5. Pharmacist mathematical errors will be less than technician mathematical errors when using the computer.
Hypothesis 6. Accuracy of computer assisted review of order items for appropriateness will be higher than manual review of order items for appropriateness.

Hypothesis 7. Accuracy of pharmacist review of order items for appropriateness will be higher than technician review of order items for appropriateness when using the computer.

Hypothesis 8. Pharmacist confidence in determining appropriateness will be higher than confidence for manual appropriateness review.

Hypothesis 9. Pharmacist confidence in determining appropriateness will be higher than technician confidence in determining appropriateness when using the computer.

Hypothesis 10. Composite performance for computer assisted appropriateness review will be higher than composite performance for manual appropriateness review.

Hypothesis 11. Pharmacist composite performance in determining appropriateness will be higher than technician composite performance in determining appropriateness when using the computer.

Hypothesis 12. Pharmacist perceived importance of responsibility for reviewing order items for appropriateness will be higher than that of technicians.
Hypothesis 13. Pharmacists' willingness to enter additional input data will be higher than that of technicians.

Hypothesis 14. User willingness to enter additional input data will be directly related to perceived importance of responsibility for reviewing order items for appropriateness.
DEFINITION OF TERMS

ADOLESCENT: A patient greater than 12 years of age and less than 16 years of age.

ADULT: A patient greater than 16 years of age.

ALGORITHM: A list of steps that a computer program will follow to carry out a task.

APPLICATIONS SOFTWARE: Programs that perform job functions on a computer are termed applications software. Word processing is one application; spread sheets another. Users purchase spreadsheet programs to perform financial projections, graphics programs to make charts and graphs to illustrate financial reports, and database management systems to set up master filing systems that keep records in whatever order desired. Various programming languages, such as Basic, Fortran, Pascal, Mumps, Lisp, Prolog and decision support development shells are types of application development software that allow the user to custom design programs. Each programming language has unique characteristics, advantages and disadvantages depending on the nature of the intended use.

Numeric equivalents given to letters in early teletype systems produced the basic principle for word processing software. Some computers are built for that function only
and are known as dedicated word processors. The personal computer is capable of running word processing programs such as Wordstar as well as other applications software such as spreadsheets using a Lotus 1-2-3 program or a programming language such as Turbo-Pascal, given appropriate memory capability.

APPROPRIATENESS: Measurement of a subject's ability to identify potentially inappropriate order items, measured as a number of correct responses to twelve order items questions (with a possible range of scores of zero to twelve). (See Drug Therapy Problem Solving and Information Intervention.)

ARTIFICIAL INTELLIGENCE (AI): The branch of computer science engaged in making computers behave in ways that would be considered intelligent in a human being.

ARTIFICIAL LANGUAGE: A language whose terms are unambiguous and designed for a single purpose, such as computer programming or music notation.

ATTRIBUTE: A characteristic of an object; for example, age and weight are attributes of a patient.

BACKWARD CHAINING: A control mechanism that seeks to satisfy a stated goal by seeking rules in which the THEN portion matches the goal, then seeking other rules whose
THEN portions match the IF portion of the rule which satisfies the goal.

CALCULATION TIME: Time required to generate or perform TPN formulation calculations.

MANUAL CALCULATION TIME: Time to complete formulation calculations of the TPN and fat emulsion solutions using a pencil, hand-held calculator and a preprinted protocol worksheet.

COMPUTER CALCULATION TIME: Time for the user to generate a mixing instruction worksheet, measured from the selection of the mixing instruction printout until the printed mixing instructions are removed from the computer's printer.

CENTRAL PROCESSING UNIT (CPU): A microprocessor, sometimes called the "processor". In most microcomputers, the central processing unit, or CPU, is in the same cabinet as the disk drive; in some it is located in the cabinet space with the monitor or with the keyboard. The central processing unit follows instructions relayed to it from the terminal or from software. Obeying those instructions, the processor receives information, rearranges it, stores it in a safe place and retrieves it for later use.
CERTAINTY FACTOR: (Also CONFIDENCE FACTOR) A numerical value assigned to a statement of fact or a conclusion to indicate one's confidence that it is correct.

CHILD: A patient greater than one year of age and less than 12 years of age.

CHIP: The silicon-based element which contains the computer's microprocessor. The chip contains electronic circuits.

CLINICAL REPORT TIME: Time measured for user to select clinical report printout until the clinical report is removed from the printer.

COMPOSITE PERFORMANCE: Measurement of subjects combined confidence and accuracy in identifying order item appropriateness. The sum of confidence scores for incorrect responses minus the sum of confidence scores for correct responses.

COMPUTER: An electronic memory device that is able to follow a set of instructions in a program.

CONFIDENCE: Measurement of a subject's self-assurance that his determination of appropriateness is correct. Range of scores: total guess 50% to complete certainty 100%.
CONSULTATION SYSTEM: A decision-support system containing a small to very large body of knowledge and supplying the user with descriptive and/or prescriptive information depending on the design of the inference engine.

CONTROL MECHANISM: The method used by an inference engine to determine how a system will reason to a conclusion. Forward and backward chaining are two control mechanisms.

COST BENEFIT ANALYSIS: Program evaluation technique that summarizes the monetary benefits of the program as an index of the cost of the program. The index is known as a cost benefit ratio.

COST IMPACT ANALYSIS: A program evaluation technique that measures and identifies the costs and selected impacts of interest to the evaluator of a specific program.

COST EFFECTIVE ANALYSIS: A program evaluation technique to provide decision makers with identification and/or quantification of comparative program costs and selected impact measures among two or more program alternatives.

CRT: Cathode Ray Tube: same as a television screen but located on a computer terminal.

DISK DRIVE: The computer component containing slots for insertion of flexible disks. The disk drive is the mode
whereby information and instructions to the computer are recorded for future use.

DOMAIN: An area of expertise.

DRUG THERAPY PROBLEM SOLVING AND INFORMATION INTERVENTION: A non-distributive pharmacy task comprising: (i) reviewing patient orders for appropriateness, i.e., identifying potential overdoses, underdoses, drug interactions, potential allergic reactions, suboptimal product selection or dosing regimens or other contraindications; and (ii) prescriber consultation supplying drug therapy information for optimal cost-effective rational therapeutic alternatives.

The process impacts patient care by promoting rational cost effective drug therapy, decreasing potential medico-legal liability from drug induced iatrogenic illness and seeking improved prescriber habits through effective consultation and education.

EXTERNAL MEMORY: DISK STORAGE: A storable and retrievable memory device where the contents of Random Access Memory is written for safekeeping until its use is required.

EXPERT SYSTEM: A decision support system containing a body of knowledge derived from one or more experts in a particular field.
FLOPPY DISKS: Disks or tapes made of mylar where information is stored in the form of magnetic particles. Because the disks are flexible, they are called floppy disks, microfloppies or diskettes. Disks are encased in a square hardboard or light plastic envelope to minimize exposure of the magnetic mylar exposed. Diskettes can be 3 1/2, 5 1/4 or 8 inches square, depending on the machine on which they are to be used.

FORWARD CHAINING: A control mechanism that seeks to identify all rules whose IF portions are true, then uses the THEN portions of those rules to find other rules which are also true.

HARD DISKS: Hard, or "fixed", disks hold considerably more information than a floppy disk and are permanently installed in the machine. Microcomputers may contain both floppy disk drives and hard disk drives. Information on a disk is organized into chunks called files. Individual groups of information within a file are referred to as records while individual data items within a record are called fields.

HARDWARE: The mechanical and electronic components of the computer system. The system generally contains a keyboard, a video screen and a disk housing. The components may be built into one cabinet or connected by wire or cable.
HEURISTICS: Rules of thumb and educated guesses that an expert uses in solving problems in his or her domain.

HIERARCHY: An arrangement of concepts or objects in which some are subordinate to others.

HIGH LEVEL APPLICATION: A program that supports user decision making, one time inquiry, or unique user developed needs. Also a commercial application development program that allows the microcomputer user to design a program application to suit individual user decision support or information needs.

HIGH LEVEL LANGUAGES: The further a language departs from the actual circuits of the CPU chip, the higher its level. An English-like programming language such as BASIC is an example of a "high level language".

HIS - HOSPITAL INFORMATION SYSTEM: A computer hardware and software system, consisting of a mainframe or minicomputer and a network of terminals throughout the hospital, and a software application supporting several low-level departmental functions such as: admissions, business office, billing, pharmacy, laboratory and others. An integrated system allows multi-department users to benefit from a single shared hospital/patient database, and to access the system from any terminal location.
INFANT: A patient less than one year of age and greater than 30 days of age.

INFERRENCE ENGINE: The part of a knowledge based system that contains the procedures for reaching a conclusion.

INPUT: The instructions or data that are put in to the computer by an input device like a terminal or card reader.

INTERFACE: The place where two elements in a computer meet. The USER INTERFACE is the part of a computer program that is visible to the person using it.

INTERNAL MEMORY: ROM AND RAM: The computer has three types of memory, two of which, ROM and RAM are contained in chips within the machine.

KEYBOARD: The device which permits the user to input information and instructions to the computer.

KNOWLEDGE BASE: The body of facts, rules and heuristics which form the basis of a knowledge system.

KNOWLEDGE-BASED SYSTEM: Also KNOWLEDGE SYSTEM, a decision support program containing a knowledge base and an inference engine; an expert or consultation system.

KNOWLEDGE ENGINEERING: The task of acquiring knowledge, designing and building a knowledge based system.
LABEL GENERATION TIME: The time required to prepare a TPN label.

MANUAL LABEL TIME: The time required to type a TPN label and a fat emulsion label on an IBM electric typewriter using a preprinted label format.

COMPUTER LABEL TIME: The time required for the operator to input the data and for the computer to generate a TPN label and a fat emulsion label on the printer, measured from the start of order input until the labels are removed from the printer.

LISP: For LISt Processing. A programming language widely used in artificial intelligence research.

LOW LEVEL APPLICATION: A program that essentially performs routine repetitive data processing activities on a large data base. Low level applications perform routine database clerical functions such as maintaining profiles, inventory and billing information and rarely support user decision making.

MAINFRAME COMPUTERS: Powerful processors used by institutions or business for large scale database management applications and multi-tasking applications.
MEMORY: BITS, BYTES AND CAPACITY SIZE: A computer deals with only two bits of information: zero (0) and one (1). The information and instructions given to a computer by the user are translated into a code composed solely of zeroes and ones that turn electric current on and off. Each zero or one is called a bit - short for binary digit. Eight bits equal one byte.

MEMORY CAPACITY: Memory capacity is measured in kilobytes, which are thousands of bytes, written as Kb or just plain K. A kilobyte contains 1,024 bytes. A double-spaced, typewritten page contains about 2,000 characters or 2K of information. Microcomputers generally are equipped with 256Kb or more.

META-KNOWLEDGE: Information about other information in a knowledge base, such as the text of a question that asks the user to enter data at the keyboard.

MICROCOMPUTERS: The newest members of the computer family, often called personal computers. The unit may be, but is not always, self-contained units which may or may not be able to get information from minis or mainframes, or give information back to the larger machines. Due to recent technological advances it is now possible to link all kinds of computers so that they can swap information which has expanded the role of microcomputers.
MINICOMPUTERS: Minicomputers are generally smaller than mainframes both in physical size and in the number of people who can use them at one time.

MIPS: In data processing, Millions of Instructions Per Second, measure of the performance speed of a computer system.

NATURAL LANGUAGE: The languages that people speak, full of nuance, ambiguity and subtlety, a branch of AI research is engaged in trying to make computers understand natural languages.

NEONATAL HYPERALIMENTATION: A therapeutic modality consisting of the total or supplemental nutritional support by a parenteral solution of amino acids, dextrose, electrolytes, vitamins, trace elements, other intravenous additives and fat emulsion therapy to maintain metabolic functions and growth, in a neonate.

NEONATE: A newborn patient, either term or premature, less than or equal to 30 days of age.

NODE: A decision point in a rule-based system.

OBJECT: A concept or physical entity which possesses any number of attributes; for example, in a patient tpn order database, the patient is an object, the patient's name,
weight, grams of protein received per 24 hours, age, etc. are attributes.

OPERATING SYSTEM: The operating system serves the CPU by acting as an interpreter. It takes the information and instructions that come from terminal and disk and translates them into the machine's language. Loading the operating system is referred to as "booting the machine". The operating system determines what programs the user will be able to run and what capabilities the computer will have. The most common microcomputer operating systems are PCDOS and MSDOS. Some of the other microcomputer operating systems are CP/M, Unix or Venix, and p-System.

OUTPUT: The data that a computer provides as an answer to a problem or in response to a request. Most common forms are printed output on a CRT screen or printed output in a hard copy (paper).

PASCAL: A high level programming language developed by Nicholas Wirth. The language is suitable for a variety of applications including simple data processing programs and artificial intelligence oriented applications. The programming language compiler supports local and global variables, modular problem solving procedures, and a variety of logic control statements.
TURBO PASCAL is a commercial version of standard Pascal by Borland International, Scotts Valley, California. Enhancements over standard Pascal are: supports include files, program chaining, text file variables, and an ultra-fast, semi-interpretive user-friendly compiler programming development environment. TPN.COM was written using TURBO PASCAL.

PC AND MSDOS: The most common operating system by far is called MSDOS (DOS stands for Disk Operating System.) The IBM PC uses a version of MSDOS called PCDOS. MSDOS is the generic name for this operating system, and any reference to MSDOS in this project can be understood to refer to PCDOS as well. More business software is written to run under the supervision of MSDOS than under any other operating system, so it's easier to find software that will do what the user wishes it to do if he has a machine that runs MSDOS. This research project involved a custom designed program written in Pascal using Borland's TURBO PASCAL software running under MSDOS, which means that it works on the IBM personal computer and other machines that use the same operating system.

PERIPHERALS: Accessorial functions and equipment which enable the CPU to perform tasks such as printing and transmitting over a telephone modem.
PERSONAL COMPUTERS: Computers which the user may operate with little to no expert assistance. Their advent in business was occasioned by the need for a computer which was not dependent upon data processing professionals to produce the custom generated reports desired by managers and the inability of vendor-supplied software to be customized for one time inquiries or custom applications with a short life cycle. The personal computer supports individual user needs for word processing, spreadsheet, database or an interactive programmable system. This project uses the terms personal computer, micro, and microcomputer interchangeably.

PREMATURE: A patient of less than 36 weeks gestation.

PRIMITIVES: Built-in functions in LISP.

PROGRAMMING LANGUAGES: Language that turns the instructions input by the user into a basic language, assembler, which the operating system then translates into machine code, i.e., zeroes and ones.

PROLOG: For PROgramming in LOGic, a language used in AI research.

PROGRAM: A set of instructions used to operate a computer.

PROGRAM EVALUATION: Systematic examination of specific inputs, activities, and outputs to provide information on the full range of the program's short and long-term effects.
RANDOM ACCESS MEMORY (RAM): The work table onto which the user places the instructions (programs) for the job at hand and the information (data) with which the user desires the computer to work. RAM is short term memory; if the power goes off or the computer is shut down, anything stored in RAM is gone forever. For this reason, RAM is sometimes referred to as a volatile memory and because the computer cannot function without RAM, it is also called main memory, or sometimes just plain memory. The terms RAM and memory are used interchangeably in this paper.

READ-ONLY MEMORY: The memory built into the computer by its manufacturer. It contains instructions that start the computer when the user turns it on and may contain other programs as well. Nothing the user does will change the instructions written into ROM.

RECURSION: A technique in computer programming in which a function calls on itself to solve a problem.

REVIEWING ORDERS FOR CLINICAL APPROPRIATENESS: An attitudinal measurement derived from a seven point likert scale, measuring subjects perceived IMPORTANCE of pharmacy's responsibility to check orders for appropriateness.

SOFTWARE: Computer programs which provide framework of instructions for the computer to utilize in working with the
information provided by the user. The terms software and programs are used interchangeably in this paper.

SHARED RESOURCE COMPUTER (SRC): A single mainframe or minicomputer supporting multiple users, whose application software is usually devoted to low-level bottom line business applications.

STAND ALONE SYSTEM: Any computer system not linked to other systems is a stand alone system. In management information systems jargon a stand alone system is usually a mainframe, mini or microcomputer supporting one or many terminal users, but whose software application supports a single department.

SYLLOGISM: In logic, a statement consisting of two premises and a conclusion.

TERM: A newborn patient of 36-42 weeks gestation.

TERMINAL: An input and output device for a computer. Usually looks like a typewriter keyboard with or without a screen or printing device. A video screen and keyboard, taken together, are referred to as a terminal.

TOTAL TASK TIME: Label generation time plus calculation time (plus clinical report time for computer).

MANUAL TOTAL TASK TIME: Manual label generation time plus manual calculation time.
COMPUTER TOTAL TASK TIME: Computer label generation time, plus computer calculation time, plus mixing instructions and clinical report time. Measured as the time from the start of order input until the user obtains the printed labels, mixing instructions and a clinical report.

UTILITY MEASURES: Cost effective analysis impact measures defined as: label generation time, calculation time, total task time, mathematical errors, appropriateness, confidence.

WILLINGNESS TO ENTER ADDITIONAL INPUT DATA: An attitudinal measurement derived from a seven point likert scale, of subjects' willingness to enter 12 to 35 additional laboratory and clinical patient data parameters given the premise that a much more detailed and sophisticated order appropriateness clinical report based on trend analysis of current and previous patient orders, clinical parameters and laboratory values would be computer generated.
CHAPTER 2

LITERATURE REVIEW

This project is concerned with evaluating the use of a microcomputer application to assist distributive and non-distributive professional tasks in the preparation of neonatal hyperalimentation. The project utilized a context-input-process-output evaluation model. A literature review was conducted corresponding to each component of the project model.

Chapter 1 discussed the evaluation of the "Drug Use Control" practice model as the key mission of the pharmacy profession. The historical advent of unit dose and intravenous admixture programs actually expanded manual labor intensive personnel requirements. These distribution systems were an impetus to the clinical pharmacy movement. Reviewing physician orders to detect clinical appropriateness emerged as a major non-distributive professional task.

Chapter 2 continues with a review of professional factors associated with effecting drug use control. The evolution of computer technology and the current status of the adoption of computer applications in hospital pharmacy is followed by a literature review of nutritional support.
Factors Affecting Drug Use Control

The current concept of pharmacy practice has evolved to encompass both distributive and non-distributive tasks to affect the goal of drug use control. Role conflict, expanding clinical services and finite resources have evolved as both positive influences and obstacles to realizing professional goals.

Historical Prospective: Role Conflict

Pharmacy in its most traditional sense has long been concerned with the manufacture (compounding) and distribution (dispensing) of drug products intended for the patient. In 1240 A.D. Frederick II, the ruler of the Holy Roman Empire, directed the separation of the practice of medicine and pharmacy. Pharmacists have focused their attention on the area of dispensing while physicians have assumed the role of diagnosing and treating patients. However, the distinction has never been totally clear (Silverman and Lee, 1974). For years pharmacists continued to diagnose and treat patients. They advised patients about common illness, dispensed remedies and acted as "physicians to the poor" (Kremers and Urdang, 1976).
The patient-oriented approach to the practice of pharmacy eroded greatly in the early part of this century due to the mercantile aspects of pharmacy as a business (Brodie, 1976). Even today, "drug stores replete with advertisements for every imaginable mercantile good, taint the image of pharmacy" (Francke, 1969).

Several attempts at changing the focus of pharmacy practice and education to a "clinically patient oriented practice" were voided in the 1930s and 1940s but failed to materialize (Francke, 1974).

As developed in the first chapter, the clinical pharmacy movement began to evolve in the 1960s as a result of the growth of complex distribution systems. Early leaders in the clinical pharmacy movement perceived the poor use of the lack of application of drug knowledge. The main thrust of "clinical pharmacy" is aimed at enhancing the benefits of drug therapy by detecting deficiencies in the drug use process. Brodie's concept of drug use control helped unite clinical pharmacy concepts and hospital distribution requirements of unit dose and intravenous admixture services into a unified concept of practice and professional mission (McLeod and Miller, 1981).

Role Conflict

Pharmacy schools have adopted their curriculum and advanced training programs to meet the needs of a clinically
oriented practice. The quality and complexity of innovative clinical pharmacy services has increased remarkably in the past decade (McLeod, 1976).

Despite these successes, pharmacy as a profession has not realized its goals. Nor can it claim reliability in effecting total drug use control.

One problem is a growing dichotomy between the knowledge and training of the full-time, highly trained clinical pharmacist and those who continue to merely prepare and dispense drugs as their primary activity. Just as retail pharmacies have hindered the image of the clinical hospital practice role, the image of the clinical pharmacy practitioner has been by traditional hospital pharmacist (McLeod and Miller, 1981).

In 1976, Dr. Francke commented on the levels of pharmacy practice. He stated that 90% of traditional dispensing activities could be performed by technologists. This could free pharmacists to perform high level clinical drug therapy monitoring, drug therapy problem solving and drug information intervention activities. This level of practice would not promote abdication of distribution responsibilities. Rather, pharmacists would elevate their status to a distribution systems manager and expand the professional horizon to include reliable drug therapy monitoring and effect optimal drug use (Francke, 1976).
The adoption of the use of support personnel has been hindered by the dichotomy in clinical training and clinical practice positions. High level clinical practice positions have emerged slowly in a few teaching hospitals. Not all pharmacists agree with the extent of responsibility of pharmacy to monitor drug therapy for appropriateness. Some pharmacists seek job protection and would disfavor allowing technicians to assume greater responsibility. The laws governing pharmacy practice, and the philosophies of individual state boards of pharmacy have not greatly changed to encourage or facilitate clinical practice roles (McLeod and Miller, 1981).

Pharmacy Information Gap

New graduates of Pharm.D. programs and advanced specialty trained pharmacists encounter other obstacles to employing clinical pharmacy skills to effect drug use control. The problem is one of patient, prescriber and information access. A highly trained pharmacist cannot recognize inappropriate orders, monitor drug therapy or perform effective drug therapy problem solving intervention without access to the patient, patient information, laboratory data and other members of the health care team. Most hospital pharmacists are employed in "centralized basement dispensing operations" far removed from the patient
care area. Even with access to computerized laboratory data, it is difficult to effect reliable drug use control.

A few innovative directors have adopted formal clinical services and certain innovative practices such as decentralized satellite distribution systems that place the pharmacist in a setting where he can access information and exercise more effective drug use control activities (McLeod, 1975).

Finite Resources

Advanced education, expanded use of technicians and unique practice positions may not be a total solution to effecting reliable total drug use control.

One aspect of the problem is related to the complexity of medical knowledge. Effective patient monitoring is a time consuming task. The pharmacist must review the patient's drug history, diagnosis, problems, physical findings, laboratory data, parameters such as weight and age, allergies and current regimen to fully determine drug therapy appropriateness.

Few hospitals can afford to provide a specialized, highly trained clinical pharmacist for every service. For example, few hospitals could afford or justify all of the following clinical pharmacy specialists: general satellite pharmacists, an ICU specialist, a NICU specialist, a pediatric specialist, a CCU specialist, a pharmacokinetic
specialist, a drug information specialist, etc. Hospital pharmacy departments must plan their priority need for their own institution.

It is impossible to keep up with medical advances in several fields of clinical practice and yet most "clinical pharmacists" must function as generalists and adapt themselves to wearing many hats (Provost, 1972).

In the past few years the health care system has been faced with an ever-increasing elderly population, consuming a disproportionate amount of resources compared to a dwindling post baby boom working population. This trend will continue past the year 2000 (Bootman and Noel, 1986). Of particular concern is the fact that health care costs have spiraled upward at a rate of inflation that has continually outpaced increased in other consumer goods and services (Oddis, 1984). The proportion of gross national product devoted to health care rises each year.

Medicare and Medicaid legislation was enacted on July 30, 1965. Congress appropriated money to help pay for the rising cost of health care to ensure health care benefits for the indigent and to assist the annuity benefits of the elderly retired (Smith and Brown, 1979). The result was a dramatic increase in demand for health care services. There was no incentive for consumers of health care to be frugal buyers.
Legislators, economists and health administrators have long been acutely aware of spiraling demand and cost of health care and the realization that resources are finite. In 1984 Congress enacted the Social Security Act Amendments of 1983 that incorporated prospective pricing by diagnosis-related groups (DRGs). Under DRGs, hospitals are reimbursed not retrospectively, but on the basis of prospective, predetermined rates falling in one of 467 DRG categories. Hospitals are now receiving a flat fee per diagnosis per patient, no matter how much or how little care the patient actually receives. Moreover, this prospective, "flat-fee" basis for reimbursement is being adopted increasingly by third-party payers. The latest development has seen the advent of prospective capitation financial reimbursement.

Health care administrators have been under tremendous pressures to keep costs down. The impact of these changes have placed pressures on pharmacy. Pharmacy departments have shifted from a revenue producing department to a high cost area. Many departments were faced with hospital-wide mandatory personnel cuts, forcing departments to curtail clinical services and recentralize their operations.

Pharmacy can no longer sell expanded services and personnel additions merely because these programs demonstrate improved quality of care. Administrators have become critically aware of the need to evaluate program
costs and personnel productivity based on improved case mix profitability.

While changes in hospital reimbursement have placed stringent limits on personnel and financial resources, these same changes have increased the need for pharmacy services.

Prospective pricing has changed the characteristic of the inpatient population. The acuity of patients has risen sharply. The "sicker" patient has required more drugs, more expensive drugs and particularly more labor-intensive intravenous drug therapy. These patients are more complicated and require more intensive clinical monitoring.

Administrators are simultaneously looking to pharmacy as a resources to decrease costs through increased participation in drug therapy decision making for individual patients through prospective interactions with prescribers. Thus pharmacy has experienced personnel restraints and cutbacks while being charged with increased distributive and non-distributive tasks.

Personnel are a major departmental expense, and it is this limitation which appears to determine the extent of pharmacy services. Clearly, pharmacy must seek other innovations to improve productivity.

Many hospitals have adopted computerized applications to assist and automate pharmacy tasks. Those that have not computerized soon will (Penna and Knapp).
Growth in Computer Technology

The science of computer technology was in its infancy thirty years ago. Between the production of ENIAC in 1946 and the first year of the next decade, 1950, there were only thirty computer in existence. As with most new technologies, the growth in terms of product numbers was slow in the next twenty years because of the expense of production, the limits in electronic circuitry and the need for basic research. By the year 1970 the number of computers had multiplied to 30,000 units in the United States, but their cost, size and efficiency and specialized operating requirements still limited their application to big business and government.

In 1975 the manufacture of the first integrated circuit chips lead to the development of the small computer. The chips not only increased the electronic efficiency of computers, but had the added benefit of decreasing the cost of small computers. The growth of computer use from that point in time to the present day has been exponential. By 1980 there were 230,000 computers in use in the United States which accounted for 54% of all computers in the world, 80% of which were produced in the United States (Browning, 1983).
Medical Information Systems:

Computer Technology Applications in Pharmacy

Advances in computer technology applications promise revolutionary advances in the information age. The information age is for medical computing applications drowning in the data age. Never before has there been so much data, and so little access to useful information. Failure of medical information systems (MIS) to meet the needs of health care managers and clinical professionals is due to the proprietary syndrome and the level of organizational maturity in adopting new technologies. MIS computer technology applications have been shaped by the professional needs for computer assisted information services in the health care setting. The converse is also true. A particular computer application can dramatically shape the role of the professional, serving to either expand or limit the level of professional service provided. Sophisticated end-user computing power, made available by technological advances in hardware and software integration, networking and communications, will soon be a major segment of information systems in most large organizations. The purpose of this section is to review the status of MIS applications and to examine future trends, emerging issues and professional implications for pharmacists.
Technological developments have shaped the fabric of society, exerting powerful influences on the vocational endeavors of the working masses. Consider the following historical landmarks in technology and their effects on occupations. In the stone age man was a hunter gatherer. The bronze age brought forth an agrarian society. The iron age ushered in the "second wave societal transformation" characterized by uniform mass production, tedious assembly line work and the unvarying job requirements of the urban factory worker (Toffler, 1981). Less than 200 year ago the majority of the country's population were farmers. The electronic age of the 50's, characterized by the clerical/technical worker has been succeeded by the silicone age. Dubbed the information age, manifestations of this "third wave transformation" (Toffler, 1981) of society are most noticeable in the work place. Although extant laborers and skilled craftsmen still occupy positions yet unaffected by robotics and automation, and discounting that most valuable human resource, personnel management and people skills, the majority of present professionals and support personnel are employed in the clerical movement of data and the provision of technical information. Even skilled surgeons spend the majority of their training experience not in practicing surgical techniques, but in acquiring information to manage the pre-and post-operative care of their patients. Advances in monoclonal antibodies,
immunology, genetic engineering and recombinant DNA techniques portend the genetic age of molecular level biological information (Office of Technology Assessment, 1985). Some patient profiles now contain an individual diagnostic and/or therapeutic genetic cell marker code. Rational therapy depends on that database. Futurists describe the coming age as the "World Brain", world-wide immediate information access. The role of the professional within his/her technical specialty service in this coming age will evolve as an applied information/knowledge engineer (Joseph, 1982).

Pharmacy, like other professions, is being inextricably caught up in the information communication era. The American Society of Hospital Pharmacists has identified the three prominent components of pharmaceutical services as: (1) the procurement, distribution and control of all pharmaceuticals used within the facility; (2) the evaluation and dissemination of comprehensive information about drugs and their use to the institution's staff and patients; and (3) the monitoring and assurance of the quality of drug use. The evolution of each component of professional services has required increased needs for timely and accurate information systems. While the technical skilled art of compounding has been de-emphasized, complex dispensing systems, large scale inventory control, increased governmental regulations and
record keeping and multiple fiscal billing requirements have created the need for information systems to assist in these labor intensive manual systems. "Pharmacists spent more time in the preparation of medicines for dispensing thirty years ago when dosage forms were compounded by the pharmacist than today when almost all prescriptions are filled with commercially prepared products. ... During this time the number of drugs has dramatically increased ... The amount of information that a pharmacist has been required to learn, retain and use has increased more rapidly than the number of drugs." (Burleson, 1982) The later components of pharmacy services are characterized by clinical drug therapy information intervention. The fundamental change in the nature of the profession from skill dispensing pharmacognocist to drug information expert underscore the transformation of the professional in the information age.

Controlling INFOSPACE

Applying computer applications to the information needs of the professional is the process of controlling "infospace" (information systems planning for automated control and efficiency). The purpose, feasibility, functional efficiency, professional user and end beneficiary organizational impact of an information system (IS) or a
single component application can be analyzed within the framework of the infospace model (Joseph, 1982):

Table 3. INFOSPACE MODEL

<table>
<thead>
<tr>
<th>DATA INFORMATION</th>
<th>ORGANIZATIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONVERSION</td>
<td>DOMAIN</td>
</tr>
<tr>
<td>1. data source content and format</td>
<td>1. source-ownership</td>
</tr>
<tr>
<td>2. access vector</td>
<td>2. user</td>
</tr>
<tr>
<td>3. manipulation processing</td>
<td>3. user</td>
</tr>
<tr>
<td>4. delivery vector</td>
<td>4. user</td>
</tr>
<tr>
<td>5. information content and format</td>
<td>5. end-beneficiary</td>
</tr>
</tbody>
</table>

The components of the infospace model are characterized by the conversion of data to information and its functional organizational domain. The process of converting data to information is a dimension circumscribed by a data source, an access vector, a manipulation process and a delivery vector. Data has both content and format. Its format may entail paper records or electronically stored code. Data is not useful information per se until its content and format are accessed, manipulated and delivered by a user into a content and format useful to answer the question or purpose of the end beneficiary. The infospace model is a useful framework to understand the impact of
increasing levels of organizational maturity on the nature and extent of professional services, organizational infrastructures and management requirements.

Adoption of Computer Applications in Pharmacy: and Organizational Maturity

The adoption of computer applications for pharmacy functions are consistent with the information system (IS) organizational maturity (OM) model. Churchill et al, while evaluating an organization's adoption of state of the art computer-based information systems advanced the concepts of information systems organizational maturity. They divided the computer application development process into four stages: (a) finding quicker and less expensive models of existing manual systems (Type I); (b) extending or improving the quality of Type I systems and furnishing more extensive reports (Type II); (c) integration of previously separate systems and inclusion of decision making process applications (Type III); and (d) expansion of current applications to support strategic planning of top-level executives and use of models to facilitate ad hoc queries (Type IV) (Churchill and Kemsler, 1969). Gibson and Nolan expanded and revised their model to include organizational requirements for application development, personnel
specialization, management techniques and organization (Gibson and Nolan, 1974). The fourth stage formerly known as integration was renamed the maturity stage where computer resources reached full growth within the organization. The importance of this classification scheme is that it distinguishes the difference between basic routine (low level) applications (Type I and II), progresses to nonrepetitive decision maker oriented (high level) applications (Type III and IV), and ultimately to full scale integration of computing with resources with increasing levels of organizational maturity (Type IV).

Low Level Applications

As predicted by the OM model, the initial use of computer applications in pharmacy have been dominated by low level vendor-supplied applications. Browning, 1983, showed that 76% of hospitals were using some form of computers largely for repetitive distribution oriented tasks (Browning, Hurd, Bootman, Tansik and McGhan, 1984). Listed by decreasing order of magnitude they included: patient billing, patient lists, IV admixture labels, prescription labels, patient profiles, unit dose labels and fill lists, inventory control, and narcotic control. The time-saving labor efficiency gained by these applications is the result of the high speed data storage and retrieval of multiple relational databases, and subsequent conversion of data to
information, as a result of a minimum time labor input requirement mimicking the original manual procedure. For example, in a typical system, typing a prescription or IV label, or a unit dose entry in a manual profile is mimicked as a computer input procedure. Inventory and order control, patient profile, billing procedures, narcotic control, productivity lists or unit dose fill lists are all simultaneously supported and updated, as well as the

Low Level Type II Systems

Type II improvements of existing systems are generally limited to low level vendor-supplied applications, such as removing bugs and system glitches, modifying input and output formats and supplying predetermined reports, e.g., scheduled drugs, drugs by category or physician, and productivity reports (Gibson and Nolan, 1974). Low level and high level applications are not synonymous terms with distributive versus clinical applications. For example, an inventory and ordering procedure is a decision making process, but identified as a distributive component of pharmacy service. Monitoring for potential drug interactions, analyzing the problem and making recommendations to prescribers is a clinical service. By adding a drug interaction data base and a program to a Type I system, each new prescription is electronically referenced against the profile. A potential drug interaction is
displayed on the screen usually with additional clinical information to aid the user in analyzing the potential problem. The drug interaction program reduces the first stage of the problem solving process, problem identification, to a completely controlled automatic process. The inventory program and drug interaction program are non-transparent to the user. The programs perform their tasks, without the user's awareness or initiation, continuously on each new prescription entry. Both of these improvements to a Type I system are considered low level applications because of their repetitive nature.

Low Level Integration

The third stage marks the beginning of integration of previously separate systems. Integration is limited to low level systems. A few hospital organizations have developed their own systems with in-house data processing department resources. Some innovative pharmacists with systems analysis and programming skills made major contributions to the pharmacy (IS) development process (Browning, Hurd, Bootman, Tansik and McGhan and Bouchard, Bell, Freedy and Duffy, 1972). However, vendor-supplied software/hardware packaged systems running on "stand alone" mini, mainframe or microcomputers are recommended as the easiest to implement, the least costly and the most widely used (Derwicz and Zellers, 1973). A stand alone system
means that the resources computer, its terminals and printers solely support a single system, e.g., pharmacy, laboratory, radiology, cardiology, patient appointment and scheduling, etc. A hospital integrated system (HIS) supports all of these systems, usually from a shared resource computer (SRC), allowing access to any system from any terminal location throughout the facility, and obviating the duplication of hardware terminals, printers, modems and phone lines. Integration of separate systems extends the possibilities for useful applications: drug-lab and drug-diagnosis interaction programs; antibiogram reports (drug-organism sensitivity reports by ward or patient); etc. (Austin, 1979, Grouse, 1978 and Bail and Boyle, 1980).

Low Level Cybernetic Automation

Cybernetic automation of manual distributive tasks is a type of low level application integrated with the main (IS). Leaders in corporate factory automation, such as General Motors, have used cybernetic control of manufacturing for over a decade, employing individual micro and minicomputers, as stand alone systems, to direct robotic equipment on the assembly line. General Motors and other large corporations are actively pursuing the total integration of automated systems with the corporation's main shared resource information system, local area networks and office automation stations. The movement to provide
executive and upper management with access to monitor the production process underscores the new philosophy of corporate information systems: (a) a low level IS only supports bottom line operations; (b) total corporate productivity depends on a electronic rapid interchange of data to support the information needs of upper level management and spur creative and analytic corporate decision making and innovation (Intel Corporation, 1986).

A number of machines have been used to facilitate manual pharmacy distribution tasks. Older devices were largely artifacts of the pharmaceutical manufacturing assembly line. They were chiefly useful for prepacking set quantities of tablets, liquids, topicals and parenterals.

Electronic improvements to these devices have made them practical and efficient for single job tasks. Thus machines are being used to count a selected number of tablets or mix and compound a large volume parenteral at the time of dispensing. Cybernetic automation is achieved by linking the control of these machines to the IS resource computer. Automated Prescription Services, Pineville, Louisiana, offers an electronic interface of their counting cells with several pharmacy systems. A buffer is required for systems that batch process prescriptions or use multiple terminals in order to queue the counting process. An inpatient system, developed by Meditrol, Rapid City, South Dakota, is capable of dispensing the majority of oral
solids, liquids and injectables on the nursing station at specific medication administration times via cybernetic control of a stand alone resource computer IS. For hospitals that already have a stand alone or HIS SRC, the system can be interfaced to these resources. Cybernetic automation of a machine to perform a repetitive labor intensive manual task achieves efficiency because the process is linked to the Pharmacy IS and is initiated and controlled by a minimum input procedure. In other words, the user can keyboard a new prescription or medication order into the user's system to generate labels and profile update in the usual fashion, and immediately various machines start counting, mixing or dispensing the medicine.

Mid-Level Fragmentation

During the mid-levels of organizational maturity, computer resources are the most fragmented and disappointing. Initial user enthusiasm and an unrealistic expectation of a universal IS problem solving tool wanes with the realization of the shortcomings of the typical vendor-supplied dedicated system (Mahmood and Becker, 1985-86). Users find themselves with a "wish list" ranging from low level modifications, such as a custom label program to high level special interest applications, like TPN assessment and pharmacokinetic dosing programs, flexible query systems, report program generators, word processing
capabilities, statistics programs and applications
development tools such as spreadsheets, graphics, database
and computer programming language compilers (Dotson, 1986).

**Proprietary Syndrome**

Administration soon finds itself inundated with
systems enhancement requests, exceeding the limitations of
in-house EDP department resources and confined by the
limitations of the "proprietary syndrome" (Pantages, 1986).
Many vendors have only been in the MIS business for a few
years. Typically vendors offer a SRC linked by "dumb"
terminals, dedicated to a low level "bottom line" IS and
incapable of functioning as an interactive programmable
resource (Dotson, 1986). They are not in the word
processing or applications development program business. To
develop and offer the user an interactive system with
application development enhancements to a pharmacy or
hospital MIS exceeds the vendor's resources and potential
return on investment. Vendor companies have maintained a
narrow strategy of offering low level inflexible canned
solutions and a proprietary grip on the hardware/software
configuration and compatibility of their systems (Pantages,
1986). Vendors have a proprietary interest in the integrity
of their systems. They are quite willing to perform simple
systems enhancements at a reasonably low cost, if it
improves the general marketability of their systems, but requests for single client applications such as a customized pharmacokinetic program have an exorbitant price tag. The vendors' concern is whether the application will have lasting generic market appeal in a neat and simple package. One pharmacokinetic program cannot serve the purpose of every institution. The complexities of potential applications range from a list of drugs, models and purposes: digoxin, theophyllines, phenytoin, aminoglycosides, empiric nomogram, structured or unstructured serum sampling input, linear or non-linear regression, one or two compartment model and bayesian analysis. The need and desirability of high level clinically oriented decision support systems differ from institution to institution and need to be frequently modified as new research appears in the literature. Thus, highly customized applications, serving the interests of a few staff members and having limited life cycle, are inappropriate enhancements to the typical vendor-supplied SRC.

Unique User Designed Applications

The need for unique individual user designed infospace applications, not met by data processing departments and vendors, were initially filled by a variety of computing technologies from memory typewriters to
generate labels to programmable hand-held calculators, micro, mini and mainframe computers (Browning, 1984). Only a large university-based teaching hospital could offer their individuals professionals access to a mini or mainframe interactive system. Programmable calculators, while very limited in memory, offered a portable low cost alternative for short math intensive procedures. Of these technologies the individual/department microcomputer has emerged as a low cost powerful multi-purpose tool.

Personal Computer

In the early stages of organizational maturity unique individual and department level information needs, not encompassed by the organization's "bottom line" IS resource, receive little support or attention from administration. Data processing departments have traditionally taken a hands off skeptical attitude toward individual departmental microcomputer application development. Initially microcomputer hardware and software offered limited capabilities, characterized by data processing as a suitable toy for the home hobbyist, but a questionable allocation of resources for any serious application (McAlister and Colvey, 1981). In the late 1970's any microcomputer configured with sufficient power, memory and peripherals needed for a large scale serious application could cost as much as $25,000. However,
microcomputer hardware/software costs have decreased 25% each year since 1982 while sales figures for business and professional use have increased between 40% and 100% per year (Pantages, 1986). Today, one can purchase an MSDOS compatible with 640 K ram, 40 megabyte hard disk, two floppy disk drives, clock/calendar board, parallel and asynchronous ports, high resolution color graphics board and CRT, printer and modem for under $3,500. A large variety of sophisticated software applications can easily exceed initial hardware expenditures, but many low cost "clone" companies offer a basic set of popular word processing, database, spreadsheet, DOS and utilities software as part of their hardware package. Historically, data processing professionals were alarmed by the "instant expert syndrome" of non-professionals without systems analysis and programming skills investing time and resources developing personal limited life cycle applications with little or no planning, documentation, testing or peer review. In the early stages of organizational maturity, individual personal computing management by administration is lax, and data processing department support is limited to standardizing group hardware/software purchases and maintenance agreements (Gibson and Nolan).

Despite a laissez faire interest by administration, organizations have benefited by the use of personnel computers as a low cost versatile alternative to the
inadequacies of the organization's "bottom line" SRC (Goldenberg and Panko, 1985). Low cost word processing programs, complete with spelling checker, thesaurus, punctuation and grammar program enhancements rival the performance of dedicated word processors. They are being utilized in pharmacy to generate repetitive custom labels, newsletters, departmental correspondence and to maintain procedure manuals. For those users desiring to create their own applications, a variety of programming languages are available on microcomputers. The selection of a programming application, historically limited to aboriginal versions of Basic and Fortran, now encompasses structured languages such as Pascal, C and Modula II, and the recent emergency of decision support application shells and microcomputer versions of Prolog and Lisp used to create expert systems applications. Software companies have strived to provide powerful enhancements and user friendly efficient programming/compiler environments. Indeed the trend in software is to offer application packages that can be learned and used efficiently by the nonprogrammer. Pharmacies can now store and analyze data with a variety of data base, spreadsheet, graphics and statistics programs. Integrated packages and translation conversion programs allow the user to easily transfer or combine data (words, tables, graphs and images) among applications. For example,
a pharmacy concerned with an investigational protocol or a one time DUR can store data in a database, perform statistical analysis, create graphs and charts and combine these images with the final report created on the word processor.

The expanding use of powerful low cost personal computer hardware and software in organizations has given the individual professional both freedom and responsibility of controlling the infospace process for low and high level application requirements. Pharmacists have the freedom to develop their own small custom applications without paying for a programmer. This trend is especially important for the one time data analysis inquiry. Also, a variety of low cost off the shelf microcomputer programs for high and low level medical applications are available.

A recent survey of commercial micro-based medical software indicates available programs have doubled in the last two years. Specialty programs for computer assisted medical decision making (CMD) high level applications have quadrupled and now exceed low level office management and billing programs (Polacsek, 1985). The application of artificial intelligence techniques to CMD represents a departure from simple programmed calculations and algorithms. CMD recommendations are generated by medical rule-based inference techniques, statistical association and the hypothetico-deductive cognitive model (Reggia and
Tuhrim, 1985). Rule-based CMD systems have been developed for a wide variety of medical problems, such as diagnosing and treating glaucoma, interpreting physiological signals monitored in intensive care units, pharmacokinetic dosing analysis, nutritional assessment, staging lung cancer and estimating a prognosis and predicting drug interactions, all currently available to run on personal computers. Perhaps the most widely known system is Mycin. Now available on the microcomputer as Minimycin, its purpose is to aid in the selection of antibacterial agents to treat infectious diseases. The emphasis in CMD applications is to give the user a system whose reasoning is transparent, i.e., where the program explains the how, why and limitations of the process used to make its conclusions and recommendations. Some commercial expert systems such as Medwise allow the user to update the system with new information from the literature. CMD systems serve as an aid to patient management and user education (Reggia and Tuhrim, 1985). Third stage organizational maturity is marked by the beginning of end user computing (EUC) power to control the infospace process for high and low level applications.

Stage IV: Integration

The fourth stage of OM is characterized by communication and integration of IS resources, exemplified by the micro to mainframe link. Integrating a PC to a
mainframe SRC requires three ingredients: a transmission line between the PC and the mainframe, or host, computer; application software, which usually resides on the host but may reside on the PC or both; and hardware and software capable of turning the PC into a terminal and of understanding a host's transmission. The micro to mainframe connection is divided into two components: terminal emulation - the PC's ability to masquerade as one of the terminals that normally serve the host, and protocol conversion - the capability to translate between the telecommunications protocol of the host and that of the PC. The least expensive most common connection to a mainframe is a TTY terminal or a dedicated terminal. The dedicated and TTY terminals are "dumb" terminals in that they lack intrinsic processing power and use a pre-set host specific asynchronous (one character at a time), ASCII (American Standard Code for Information Interchange) character code, and employ the RS-232C interface to connect with the host, either by direct cabling or over a phone line through a modem. To connect a PC to a mainframe for terminal emulation requires an RS-232C interface board ($80), a modem for telephone connection ($129-$300), and software to do the actual TTY emulation. Some communication packages range in price from $35 to $350; PC-TALK III, Crosstalk XVI and Smartcom II, for example, all support TTY emulation. To
emulate a dedicated terminal that is able to communicate with its host, the user needs a kit that includes a specialized expansion board for the PC and software for both computers. DCA's IRMA family of IBM micro to mainframe link cost around $1100 for a basic kit. A protocol converter is essentially a black box that tricks the host computer into perceiving the PC as a dedicated terminal, while convincing the PC that the host is an ordinary TTY host. Controllers are devices that handle the time demands of the host computer and/or a second interfaced mainframe or minicomputer. One way to avoid the cost of special controller card kits for every PC is to link the PCs to a local area network connected to the mainframe computer (Goldenberg and Panko, 1985). Local area networks allow the mainframe to act as a server for PC networks, allowing PCs to emulate the SRC application, selectively download SRC data, upload PC information to a control cache and support electronic mail and PC to PC communication (Goldenberg and Panko).

As personal computers gain power and pervasiveness, their ability to talk to mainframes becomes more routine. Inspiring the integration movement in OM is the realization that each computer fills a niche the other cannot: Inexpensive micros can process user designed individual, unique, one time inquiries without vendor or programmer support, time-sharing costs or long delays on the SRC, while
mainframes can apply gargantuan processing power to huge centralized organizational level data bases. Estimates from International Data Corporation (IDC), a market research firm, reveal 190,000 micro-to-mainframe links currently in place, nearly double the total of a year ago, with a projected 260,000 installations by the end of 1986 (Goldenberg and Panko, 1985). PCs are now almost cost competitive with many dedicated mainframe terminals they can mimic, but the PC offers nimble and flexible versatility (what data processing buffs like to call off-line processing capability or end user computing power).

Technological advances in hardware/software integration, networking and communication are beginning to offer support and efficiency to the information needs to clinical and managerial professionals. The following hypothetical example will illustrate the efficiencies of increased OM. A staff pharmacist must prepare an agenda for a pharmacy and therapeutics committee to include an evaluation for formulary adoption of a new expensive antibiotic. The agenda should include a literature search, a cost impact evaluation for restricted versus unrestricted use and recommendations to the committee. The pharmacists would perform a literature search on a commercial on line system from a department PC to evaluate the safety, efficacy and potential usefulness of the new drug. The efficiencies
and cost/benefits of on-line literature retrieval for drug information has been reported (Sloggem, 1978, Cornell, Gatewood, Davis, et al, 1981, Madden and MacDonald, 1977). Using a TTY emulation the investigator is able to save some pertinent original articles and a bibliography directly to the PC disk. Another innovation in drug/medical information retrieval makes use of the integration of the PC with cdrom (compact disk read only memory) technology. A 4.72 inch laser disk can store up to 550 megabytes of information (about 297,000 double spaced typed pages). Micromedex, Denver, Colorado, now offers four medical information databases: POISONDEX, DRUGDEX, IDENTIDEX and EMERGENDEX on laser disk at less than the subscription cost of the microfiche systems. The laser disk is connected to a PC parallel port interface and the system is controlled by a 700 K PC/MSDOS|S compatible program, usually stored on a hard disk. Drug information retrieval is faster than a manual microfiche system. The user can read the files on the CRT or print them out on the PC printer (less expensive and more convenient than a microfiche reader/printer reproduction), or capture information to disk with ram-resident software utilities. Thus the pharmacist could incorporate or add as addenda these literature retrieval files to a word process or produced agenda electronically and obviate the need to photocopy articles or retype selected passages, charts and graphs. Efficiency depends on
electronic access, manipulation and transfer of data and information, all performed in a single setting without leaving the pharmacy work station. For the impact study the pharmacist then decides that he must evaluate all past admissions for pneumonia and bacteremia, and the respective antibiotic costs for these cases over the last year to project the maximum potential cost of unrestricted addition to the formulary. Second, the pharmacist might wish to analyze a hypothetical subset of this population limited to immunocompromised patients and cases demonstrating culture positive resistant organisms to project the cost of adding the drug to the formulary restricted to these uses. For most hospital information environments this task would require weeks of manual chart review to collect the data. Some HIS environments are capable of generating lists or custom query reports of drugs, culture reports and patient diagnostic categories, but seldom is the data in a convenient or useful format for further analysis or manipulation. The data must be laboriously re-entered into the microcomputer for end user purposes. A fully integrated IS environment allows for the rapid access and interchange of corporate and end user data to information processing. Some recent innovative hardware/software LAN environments offer access to corporate data and sophisticated fully integrated end user application tools. Cullinet's ICMS
(Information Center Management System) allows the user to access corporate data directly into dBASE III files or Lotus 1-2-3 files with Symphony Link, via their GOLDEGATE package (Goldenberg and Panko, 1985). Informatics General's ANSWER series includes: Lotus 1-2-3, d/BASE, Reflex and Cornerstone applications in a compatible LAN environment (Goldenberg and Panko, 1985). Fully integrated capabilities would allow the investigator to rapidly extract these clinical case data populations to the PC or, in the case of a very large data file, to a personal virtual drive in the LAN, and immediately analyze the data with user friendly PC application tools. Charts and tables of information from this analysis could be rapidly incorporated into the word-processed produced agenda and distributed to committee members by electronic mail. Organizational maturity is emerging in corporate ISs because several companies have put their heads together and recognized the need for integration of mainframe SRC and end user microcomputing resources.

In the early stages of OM, micro to mainframe links are hampered by the proprietary syndrome and a skeptical attitude toward the cost benefits of integration. From a technical standpoint, micros and mainframes represent two ends of the hardware/software spectrum that must be adjusted for scale. Administration tends to view micro and mainframe applications as rival and separate information resources, with micros serving individual low priority departmental
needs and diverting scarce resources from the organization's "bottom line" business mainframe SRC. A sophisticated LAN package, with a Lotus/Answer or Cullinet's GOLDEGATE integrated software package configuration, for 50 personal computers costs approximately $45,000 ($900 per PC) plus additional costs for internal boards and modems and a mainframe software package that could run well into six figures.

Organizational Maturity and Productivity

Numerous articles have suggested that office automation and fully integrated systems can provide substantial improvement to organizational productivity (Curley and Pyburn, 1982, Edelman, 1981, Keen, 1981, Montgomery and Benbasat, 1983. The emphasis of mature integrated systems is to nurture decision support and individual one time data analysis needs of middle and top level managers and technical professionals. One company cited a 50% increase in sales volume attributed to adopting a fully integrated system (Gremillion and Pyburn, 1985). Mahmood has shown that fully mature systems are associated with increased employee satisfaction, an increased employee self perception of personal productivity and an increased sense of system and data ownership and responsibility. Keen maintains that benefits of computer systems emphasizing low level bottom line business applications will soon be
overshadowed by the organizational productivity gained by office automation and integrated systems supporting management information needs (Gremillion and Pyburn, 1985).

Interdependent Infrastructures and Organizational Control

Although random access to corporate SRC data might seem desirable for improving productivity, that accessibility terrifies some DP managers because of the threat to data security, expense, need for multi-vendor contractual management and increased need for organizational data/information administrative planning and control (Goldenberg and Panko, 1985). Pharmacy is responsible for source data input and maintenance of a Type I system and is largely the end beneficiary of the system. A problem with the system is limited to a pharmacy problem. With increasing OM, supply, comptroller, physician and nursing functions become beneficiaries of the pharmacy system. A problem with one department's system component affects the entire organization. Similarly, an organization must exercise increased risk management and control of individual microcomputer applications. Third level OM microcomputer applications are the responsibility of the department. The department user is usually the designer, inputs source data and the end beneficiary. In a fully mature OM environment, end user designed applications from one department often become input for applications in another department. Thus,
the need for organizational level data administration and
information systems coordination is essential with increased
levels of organizational maturity (Gibson and Nolan, 1974).

Departmental Support and Training

In the early stages of OM, data processing support
is limited to vendor or DP maintenance of the SRC and
limited coordination of departmental microcomputer purchases
and standardization. Pharmacy departments usually establish
their own control and planning of micro applications.
Usually one or more pharmacists will act as programmer and
coordinator for microapplications. With increasing OM,
usually the DP department or a data control and support
department will emerge as an organizational infrastructure
whose responsibilities include coordination of departmental
applications, staff training and acting as a resource for
planning and developing individual departmental applications
(Gibson and Nolan, 1974).

Justifying High Level Integrated Applications

Given the expense of a sophisticated LAN, justifying
a fully mature hospital information system may seem
untenable, particularly when the exact return on investment,
i.e., increased productivity as a result of supporting the
information and decision making needs of clinical and
managerial professionals, is difficult to predict. The
return on investment of a low level bottom line IS, such as an automated billing system, is easier to predict than the cost benefits of adopting a sophisticated LAN. A LAN may allow pharmacy to preclude an iatrogenic million dollar lawsuit, or assist efforts to decrease length of stay and reduce morbidity and mortality, but the exact nature and extent of these benefits is difficult to predict. A fully mature IS supports all clinical and managerial professionals. While the certainty of any one professional application to incur cost savings is low, the number of opportunities for productive benefits is extended throughout the organization. For example, one new billing system may have an 80% chance of a 50% return on investment in five years. Establishing a LAN may offer 800 opportunities of a 5% return on investment in five years, each with a 1% probability of occurrence. Both IS investments have the same potential for return on investment in five years. Gremillion and Pyburn suggest that justifying an integrated system for management decision support and office automation should be based on organizational level composite planning with multi-department input (Edelman, 1981).

High Level Clinical and Managerial Needs

The need for increased levels of organizational maturity of hospital information systems comes from the realization that productivity of applications depends on a
fluid interchange of data and information. Little attention has been given to the clinical and management needs of professionals in developing computer systems for hospitals beyond canned reports. Microcomputer software offers the tools for information analysis and processing, but without electronic access the promise of meaningful management inquiries, concomitant DUR and ongoing scientific research is precluded by the time and labor demands of manually collecting and inputting data from paper charts and reports. Data source access and information transfer are the principle impediments to productivity in the third level of OM (Mahmood and Becker).

Computer Assisted Medical Decision Making

CMD programs such as Mycin rival the expertise of specialty consultants, and yet medical decision making applications have not been widely adopted in the practice of medicine. The medical consultation process requires a first physician to request an expert to assist in the evaluation of a patient and then make management recommendations to the primary physician. The process is both time consuming and expensive. Given the performance and potential benefits of CMD programs, it would seem they would be more widely utilized. But as McCorduck has pointed out: "CMD applications are not widely utilized, not because of technophobia, but because they are inconvenient."
Researchers at Stanford have not yet integrated the Mycin program with the HIS. The user must laboriously enter patient data from paper charts and other laboratory data from a different computer." (McCorduck, 1985) Until the use of these programs is conveniently integrated with normal routine patient care procedures they will not be useful.

Need for INFOSPACE Productivity

The benefits of information systems planning for automatic control and efficiency of pharmacy functions is emerging at a time when limited personnel resources have precluded the fulfillment of professional goals. Pharmacy has adopted the goal of controlling the drug use process, assuming responsibility for the distribution of drugs, facilitating the rational prescribing of drugs and monitoring individual patient oriented outcome. A hospital pharmacy staff is charged with furnishing specialized and esoteric patient oriented drug management skills, such as monitoring neonatal pharmacokinetic and hyperalimentation, following adult medical, surgical, psychiatric, pediatric and a variety of other specialized patient populations, performing organizational level analytic studies such as budgetary, DUR and investigational research, all while maintaining traditional distributive functions. Few pharmacies are adequately staffed with specialized personnel to accomplish these goals. The problem is the time and
labor required to thoroughly review individual patient data to ensure rational therapeutic outcome. As a result, pharmacies have limited their services and activities to high risk patients and drug therapies. Hackneyed DURs and quality assurance studies are done as a minimal requirement, or on a crisis basis, rather than as a dedicated commitment to scientific research designed to improve cost effective patient care. Pharmacokinetic monitoring may be limited to formal consults, patients with compromised elimination, abnormal laboratory values or only one or two of a list of drugs that should be aggressively monitored. The pharmacy profession would like to be recognized for their ability to decrease iatrogenic-induced health care costs, length of stay, morbidity and mortality and drug therapy medico-legal liability, but without consistent and dependable execution its claims are unreliable.

Effect on the Nature of the Professional Role

The level of organizational maturity can affect the nature and extent of professional services. Low level vendor SRC applications have increased the efficiency of distributive services and indirectly freed pharmacists from repetitive tasks, enabling more time for clinical services and analytic managerial activities. The first automatic, efficient and consistent clinical service was made possible by a Type II drug interaction program. Despite claims by
the profession to the contrary, it is highly unlikely that pharmacists could adequately review every order for drug-drug, drug-allergy or drug-laboratory interactions with manual profiles and interaction charts. Who could remember all the interactions, the significance and therapeutic alternatives? Who had time to look them up manually? Although these applications are available on separate microcomputer programs, they are not practical because of the duplicate labor required to input data.

Those pharmacies without integrated systems will not benefit by the use of on screen prescriber alerting systems, sophisticated interaction programs or the eventual ability to link decision support analytic or CMD programs to the hospital's mainframe data source. The efficiency of CMD programs and individual one time end user managerial data analysis depends on the level of integration of HIS. Fully mature information systems will provide efficient tools to pursue meaningful clinical and managerial professional goals.

Increasing levels of organizational maturity may dramatically reshape organizational infrastructures and the nature of professional services. The efficiencies of increased OM places increased emphasis on a paperless organization. The Department of Defense's Composite Health Care System (CHCS) request for production included an almost fully electronic chart. Researchers at Stanford University
are pursuing a similar tract (McCorduck, 1985). Integration of a fully electronic chart will require physicians to input orders directly into the IS. This will obviate the duplication of effort of pharmacy technicians or ward clerks imputing orders. Why should the patient take a hand written prescription to the pharmacy, wait in line to turn it in and then wait for it to be input and filled? Rather, the physician will input the order from his office and directly initiate the filling process, label generation, profile update and batch report in the pharmacy. The prescription will be ready for dispensing before the patient arrives in the pharmacy. The same logic of this infospace process would indicate that a drug interaction should be reported to the prescriber at his terminal, alerting the prescriber to the nature and extent of a potential interaction and requiring his/her acknowledgment during the prescribing process. Prescribers will eventually prefer electronic order entry and patient management because of the wealth of information conveniently available through a fully mature system. The efficiency of this model changes the role of traditional pharmacy intervention and effectively takes the pharmacist out of the loop. Automatic controlled monitoring and information intervention will to some degree become a problem for the clinical pharmacy information architect (Joseph, 1982).
Information Knowledge Engineer

Will robotics and information systems for automatic control and efficiency make pharmacy an obsolete profession? Joseph (1982) maintains that automation causes a shift in the job market. Manual laborers are replaced by skilled operators, technicians become technologists and professionals become information knowledge engineers. High level OM does not offer a cost benefit return based on decreased labor costs, but a return on investment in productivity, particularly efficiency and productivity derived from supporting the end user computing needs of clinical and managerial professionals (Gremillion and Pyburn). One of the most successful artificial intelligence programs that has so far been written in DENDRAL, which infers the structure of organic compounds using mass spectrogram and nuclear magnetic resonance (NMR) data. The program was able to produce results that normally took teams of chemists several weeks of work. The use of DENDRAL did not result in the unemployment of scores of research chemists. Rather, the payoff was a gargantuan gain in productivity enabling the researchers to proceed in numerous new applications and areas of investigation. The synthesis of man and machine causes the profession to take a quantum leap forward beyond the boundaries defining their traditional professional role (Joseph, 1982).
Smith's vision of pharmacy practice in the 1980's observed that pharmacists have not maximized the benefits of computer technology for clinical and managerial pharmacy goals (ASHP Research and Education Foundation, 1985). The purpose of this project, in part, was to review current advances in computer technology, emerging issues and potential impacts on the nature of the profession. Advances in hardware and software technology are emerging that will provide tools to support low level distributive support and high level clinical decision making. This project identified a professional task requiring low and high level computer assisted support, developed a custom program to automate professional support needs and evaluated the cost and effectiveness of the program intervention.

Future Directions of Hospital Information Systems

The immediate future of hospital information systems will follow a course of increasing organizational maturity. Mature information systems will expand pharmacy services and productivity, both for distributive and clinical/managerial professional goals. Applications developed to enhance high level clinical and managerial decision support will ultimately overshadow low level bottom line business programs. Completely mature information systems will change the nature of professional functions and organizational infrastructures. Departmental functions will become
electronically highly interdependent, requiring a rethinking of departmental and organizational data architecture administration and information systems planning and management.

Need for Planning, Development and Evaluation

McConnell urges pharmacists to begin a process of ongoing planning for the integration of professional goals and future technological advances in the provision of health care. "Our future role may not be called pharmacists or clinical pharmacists". Planning for a meaningful role will necessitate "a joint effort with all health disciplines and those outside the health disciplines as well" (ASHP Research and Education Foundation, 1985). Pharmacists, like other professionals, are being inextricably swept up by advances in computer technology in the information age. We must participate in the planning, development and evaluation of computer application tools to advance the profession. Our understanding, research endeavors and active participation in applying computer technology to the infospace process will determine our role as architect or bee.
Artificial Intelligence

Artificial intelligence (AI) is the science of making computers behave in a manner that would be considered on a par with intelligence in a human being. In AI research attempts are being made to create an electronic model of human intelligence.

Defining Artificial Intelligence

Definitions of artificial intelligence are as varied as the number of researchers working in the field. In *Artificial Intelligence for Microcomputers*, Williamson cites the following examples, all statements made by present and past contributors to the development and study of AI:

"Artificial intelligence is the study of ways to make computers be intelligent."

"It is an attempt to make a computer respond like a human being."

"AI is a misleading term that makes people expect to get something for nothing, that is, intelligence in a computer. Artificial intelligence is the ability to a manmade system to deal with unplanned realities and survive them."

"It is the study of how to make computer do things that, so far, people do better."
"AI is the ability of a computer to resolve uncertainty through whatever processes it has available to it."

"The term is becoming so overused that it is fast on its way to becoming a buzzword."

"Artificial intelligence is the science of modeling human intelligence."

"The notion of self-awareness, or introspection, is a key component of artificial intelligence."

"If it works, it isn't artificial intelligence."

"Once you know how it works, it isn't artificial intelligence any more, it becomes computer science."

(Williamson, 1986)

Another definition offered is that of Barr and Feigenbaum who state: "Artificial intelligence is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior" (Barr and Feigenbaum, 1981-82).

History of Artificial Intelligence

To place this science in its proper prospective, it is useful to examine the historical events which have
contributed to the evolution of computers and the concomitant development of the idea of machine, or artificial, intelligence.

The term "artificial intelligence" itself seems to have originated with John McCarthy, an assistant professor of mathematics at Dartmouth College and a pioneer in the field who authored AI's principal programming language, LISP. To place a definition of AI in perspective, it should be noted that psychologists have identified 116 different kinds of intelligence in human beings, but that IQ tests measure only twelve of the 116 possibilities (Williamson, 1986).

Data Processing versus Artificial Intelligence

The storing of information for easy retrieval and the finding of connections between bits of information even where those connections have escaped the notice of the human beings are data processing applications, the most common computer applications today. Artificial intelligence, or the development of a computer's abilities for taking in information and reaching conclusions about it, is still in the infant stages although the concept is far from new (Williamson, 1986).
Legend and Mythology

Greek mythology references the concept of AI through the tale of Vulcan, the mechanic of Mount Olympus, who built servants made of gold whom he supposedly endowed with intelligence and the ability to serve him. Later, in the middle ages, Paracelsus wrote of creating a homunculus, or little man, which could think and act on its own (Williamson, 1986). In medieval Europe, Pope Sylvester II is credited with building a talking head that predicted the future by answering yes or no to questions about upcoming events (Mishkoff, 1986). Sixteenth century Hebrew legend refers to Judah Loew Ben Bezalel, Chief Rabbi of Prague, who built a robot of clay and named it Joseph Golem. This creature illustrates the need for the services of specially trained professionals to control our intelligent machines. As legend would have it, the rabbi's wife commanded the Golem to fetch water from the well. Like a literal-minded computer, Golem proceeded to empty the well, and the rabbi had to be summoned from his studies to make it stop (Williamson, 1986). This example points to the difficulties involved in creating AI, i.e., the non-specificity of natural language and the need to break down even the simplest task performed by the human mind into its myriad components.
Science Fiction

Fiction has always contained reference to AI. The classic example of Mary Shelley's Frankenstein developed into the modern R2-D2 and C-3PO of Star Wars fame and the eerily real computer named HAL from Arthur Clarke's 2001 (Mishkoff, 1986).

Pioneers

On the historical rather than the legendary side, Blaise Pascal devised his calculating machine, the precursor of the computer, in the seventeenth century followed closely by Gottfried Wilhelm von Leibniz's Stepped Reckoner, which did basic arithmetic and extracted square roots, though it required a human being to set up each step in the calculation. In both Pascal's and Leibniz's calculators, toothed gears represented numerals. Leibniz's was the first to use the binary digits — zero and one — to represent the more familiar decimal digits just as in the computers of today (Williamson, 1986).

The first automatic calculator (called a Difference Engine) which could perform highly complex mathematical calculations quickly and accurately was produced in 1822 by an English mathematician named Charles Babbage. Construction of a larger machine by Babbage that would calculate to twenty decimal places was financed by the
British government and was intended for use in navigation and ballistics. Later Babbage abandoned the Difference Engine in favor of an Analytical Engine. The upscale version was an all-purpose calculator that used punched cards for its input. Programs for the Analytical Engine were written by Augusta Ada, Lady Lovelace (daughter of the poet Lord Byron), the namesake of the programming language "Ada" (Williamson, 1986).

Calculators to Computers

The leap from calculators to computers comes with the application of principles of logic to the basic mathematical functions performed by the calculator. George Boole, another English mathematician, pioneered modern symbolic logic, the foundation of modern computer technology. Boole's algebraic logic used symbols to replace natural language. This permitted Boole to reduce the ambiguities of language to the certainty of numbers. The binary digit expressed opposite states, just as in logic problems the opposite sides of the problem are expressed in language (Shannon, 1953). Boole's work was continued into the twentieth century by Bertrand Russell and Alfred North Whitehead. Their monumental Principia Mathematica, which codified symbolic logic, produced the basis for writing instructions that permit computers to apply reason to a problem (Williamson, 1986).
Algorithms

In 1937, Claude E. Shannon at the Massachusetts Institute of Technology used Boolean algebra to describe how circuits behaved. His work demonstrated how the laws of reasoning could express the way electronic circuits behaved, and became the basis for using electronic circuits to reason. It was Shannon's contemporary, Alan Turing, however, who simultaneously constructed the conceptual model for the computer software of today by describing the algorithms. These sets of instructions for solving a problem described precisely the steps to be followed in performing a task so that a machine could carry it out (Mishkoff, 1986).

The deciphering machine called Colossus, built by Turing during World War II in England, worked on cracking the German army's communications code "Enigma" by using punched paper tape to represent binary digits which it converted to electrical impulses. It, along with IBM's Mark I, designed by Howard H. Aiken of Harvard University, in 1944, and the Electronic Numerical Integrator and Calculator (ENIAC), built by a team led by John W. Mauchly and J. Presper Eckert at the University of Pennsylvania in the mid 1940s, represented the first of the modern computers (Williamson, 1986).
The Turing Test

Turing wrote several papers in addition to his creation of Colossus. One of these started with the proposition which is at the heart of AI: "Can computers think?" Turing is recognized as the father of AI. His "Turing Test", or the attempt to determine whether or not an individual is conversing with another person or a computer, tries to answer the question of machine intelligence by testing whether or not the computer can fool the human user (Mishkoff, 1986). The following is an example from Turing's "imitation game":

Interrogator: In the first line of the sonnet which reads "Shall I compare thee to a summer's day," would not "a spring day" do as well or better?
Witness: It wouldn't scan.
Interrogator: How about a "winter's day"? That would scan all right.
Witness: Yes, but nobody wants to be compared to a winter's day.
Interrogator: Would you say Mr. Pickwick reminded you of Christmas?
Witness: In a way.
Interrogator: Yet Christmas is a winter's day, and I do not think Mr. Pickwick would mind the comparison.
Witness: I don't think you're serious. By a winter's day one means a typical winter's day, rather than a special one like Christmas (Turing).

Von Neumann Architecture

John von Neumann, who worked on the University of Pennsylvania's ENIAC, originated the concept of the random access memory and stored program characteristics which make computer what they are today. The phrase "von Neumann architecture" is commonly used in contrasting current day computers with those that are to come (Williamson, 1986).

In the burgeoning field of computer science, there were those who developed the machines which were the forerunners of computers and there were those who described the principles which could and would be incorporated into the improvement of those machines. In 1948, Norbert Weiner, for example, was to make his contribution to the field through is work on cybernetics and his theorizing that every function of the human brain could be duplicated electronically (Mishkoff, 1986).

Applications

The concept of machine intelligence covers a spectrum of academic disciplines: from engineering and mathematics to philosophy, psychology, linguistics, and
physiology. In the late 1940s and early 1950s many researchers were aware of each others' work, but it was not until 1956 that what came to be known as artificial intelligence was discussed among academicians as a unified discipline through the vehicle of a conference organized by John McCarthy, an assistant professor of mathematics at Dartmouth (Williamson, 1986). He was assisted at the time by Marvin Minsky who had earned his PH.D. from Princeton by trying - albeit unsuccessfully - to build a physiological model of the brain and Claude Shannon, a mathematician at Bell Laboratories, noted for his description of the relationship between logic and the behavior of electronic circuits. Also a participant was Nathaniel Rochester, manager of information research for IBM's research center in Poughkeepsie, New York (Rose, 1984).

Several of those who attended the conference later became active and influential in the field of AI. Minsky is MIT's current "Donner Professor of Science in the Department of Engineering and Computer Science". Arthur Samuel and Alex Bernstein of IBM independently programmed computers to play chess games, one of the first applications of AI research. It was Samuel's program, "Checker Player" which was the first program to learn from its own mistakes, thus exhibiting original behavior. Bernstein's chess game demonstrates the difference between data processing and AI.
It would be far too time consuming for the chess playing program to try each one of the millions of possible combinations for every move. Instead, the program applied heuristic principles to achieve its goal (Mishkoff, 1986).

Despite the participation of researchers and scientists from several academic disciplines, including mathematics, neurology, psychology and electrical engineering, the conference fell short of its organizers goals. The participants, so involved in their own work, were unable or unready to serve as the catalyst for the advancement of AI. The concentrated exchange of ideas which the organizers had hoped for did not come to pass, but the potential of AI was established (Williamson, 1986).

Allen Newell of the RAND Corporation in Santa Monica and Herbert A. Simon from Carnegie Tech, both of whom had attended the conference were the architects of Logic Theorist, a program that could prove the validity of theorems in Whitehead and Russell's Principia Mathematica discussed earlier. AI was not demonstrated in Logic Theorist, a program which simply tried every possible combination of symbols until something worked, but it did, in one case, discover a proof missed by Russell and Whitehead. The importance of Logic Theorist lay in its identity as the precursor for Newell and Simon's next
project, the General Problem Solver, which they began in 1957 (Williamson, 1986).

The idea behind the General Problem Solver was to build a machine, i.e., develop a software program, that incorporated problem solving techniques which could be applied to a broad range of problems. This advancement would obviate the need to write task-specific programs and would permit the more general application of programs users enjoy today.

In developing the General Problem Solver, Newell and Simon were the first to use human subjects as a resource in program development. By giving their subject problems to solve aloud, they were able to analyze the human thought process. They found that human beings reason forward and backwards at the same time, tracking the current status of a problem while simultaneously thinking backwards from the goal they are trying to reach. This technique of program development is still in use today by knowledge engineers, who create their systems by getting an expert in a particular field to think out loud about how he or she solves problems then duplicating these steps in their programming language (Williamson, 1986).

Human beings tend to think symbolically rather than numerically. Part of our "intelligence" as human beings
seems to be derived from our mental ability to manipulate symbols rather than just numbers. The traditional method of computer architecture, i.e., numeric algorithms are not and were not adequate to duplicate the nonalgorithmic nature of the human mental process (Buchanan, 1984).

In 1965, Edward A Feigenbaum of Stanford University and Joshua Lederber, director of Stanford's Kennedy Laboratories of Molecular Medicine, joined forces to develop a system for determining the structure of an organic molecule, a problem which organic chemists had been unable to reduce to pure logic due to the number of factors involved. The problem was one which fell into the realm of heuristics, a combination of intuition, rules of thumb and educated guesses. Feigenbaum and Lederber interviewed organic chemists on the methods they used to develop a picture of a molecule's structure. By using a combination of the data generally collected by the chemists on a mass spectrograph, rules and heuristics for interpreting spectrographic data, they wrote a program called DENDRAL, the basics of which are still in use commercially today, and which marked the beginning of knowledge-based expert systems as they are now known (Williamson, 1986).

DENDRAL marked the beginnings of what has been cited as pattern-matching methods which attempt to describe objects, events or processes in terms of their qualitative
features and logical and computational relationships in defining AI (Brattle Research Corporation).

It was Feigenbaum who coined the phrase knowledge engineering, the furtherance of which has continued through the present. Knowledge engineering was the groundwork upon which AI's first commercial success, PROSPECTOR, was based. PROSPECTOR developed at Stanford Research Institute to aid in the process of exploring for minerals. Among its achievements was the discovery in 1984 of a molybdenum deposit in Washington State whose value has been estimated at $100 million (Williamson, 1986).

One of the most exciting developments in expert systems and the field of AI is the application of these principles to the field of medicine. MYCIN, also developed at Stanford University, engages in a dialog with a patient's attending physician and identifies bacterial diseases of the blood, then prescribes the appropriate antibiotic therapies. It can rationalize its diagnoses and explain these to the physician through the assignment of probabilities. The system that manages MYCIN's knowledge base and reasons toward conclusions was extracted from the knowledge base itself, named EMYC1N (for Essential MYCIN) and used to build other expert systems, among them PUFF, which diagnoses
pulmonary diseases, and SACON, which advises engineers in procedures for structural analysis (Buchanan, 1984).

Today's medical expert systems are continuing to be developed at Stanford as well as by Saul Amarel at Rutgers University and Harry Pople at the University of Pittsburgh (Mishkoff, 1986).

The following timeline, which appears in Williamson's book, represents an overview of the developments in computer technology and AI.

Table 3. Artificial Intelligence Historical Timeline

1985 Large memory capability comes to desktop computers
1982 PROSPECTOR finds $100M mineral deposit
1981 Japan announces Fifth Generation Project
1975 Shortliffe develops MYCIN
1972 Colmerauer develops PROLOG
1970 Appearance of first microprocessor, the Intel 4004
1966 Weizenbaum develops ELIZA
1065 Feigenbaum develops DENDRAL
1957 Newell and Simon develop General Problem Solver
1956 Dartmouth Conference
1955 McCarthy develops LISP
1950 Turing defines test for machine intelligence
1948 Wiener's Cybernetics published
1944 ENIAC developed at University of Pennsylvania
1937 Shannon describes electronic circuit in binary terms
1847 Boole develops algebra of logic
1832 Babbage develops Analytical Engine
1672 Leibniz develops Stepped Reckoner
1642 Pascal develops calculating machine (Williamson, 1986)

Since DENDRAL was developed in the 1960s, one branch of the AI community has been working on developing expert systems while the other has been engaged in finding ways to bridge the gap between the languages computers understand.
and the natural languages that human beings speak. Attempts during the 1950s to build a machine that could translate from one natural language to another has made researchers poignantly aware of the difficulties in translating the ambiguities of natural language (Mishkoff, 1986 and Williamson, 1986).

Joseph Weizenbaum was one of the first to attempt to resolve this problem with his program called ELIZA, aptly named after the central character in George Bernard Shaw's Pygmalion. ELIZA's most famous implementation is a non-directive psychiatrist which can ask questions that seem to be based upon an understanding of what the person at the keyboard types into the system (Williamson, 1986).

ELIZA was equipped to analyze the syntax of a sentence and turn words around to form apparently relevant questions. Referring back to Turing's test, it must be kept in mind that if the computer is to be said to be intelligent, the dialogue it produces must be clearly "thoughtful". Although it is currently possible to use clever programming techniques to ask predetermined questions and parrot back segments of the user's responses in furtherance of the conversation, as was done in ELIZA, such programs are not considered to have passed the Turing test (Mishkoff, 1986).
By the early 1970s, researchers in natural language processing were developing systems that could understand the meanings of words - their semantics - from the context in which they appeared. One of these, LUNAR, was built to analyze rocks brought back from the moon. It was equipped with a 3,500 word vocabulary based on the types of questions that geologists ask, with models of the sentence structures they use to ask them (Williamson, 1986).

In creating the program SHRDLU, Terry Winograd of Stanford built a system in which analysis of context and semantics went on simultaneously, unlike its natural language predecessors. To demonstrate how this worked, Winograd created a world of blocks - not three dimensional blocks, but representations of them in a computer program - an imaginary robot that followed instructions to move the blocks and then answered questions about what it had done. SHRDLU could tell the user how its blocks were arranged at the moment, and make plans and carry out instructions such as "Put the green pyramid on top of the big red block." It could also tell the user which blocks it would have to move to do what it was told. It could tell when the user input a word it did not know and add new words to its vocabulary (Williamson, 1986).

Since then other natural language processing systems have demonstrated rudimentary understanding of a universe
larger than Winograd's blocks world. Experimental mainframe systems exist today that can read and summarize news reports. The value of such a system in the present era of exploding information is easy to see. And, of course, a major use for natural language processors is to get information out of a data base without having to learn the computer's language (Williamson, 1986).

The commercial applications of AI have not been lost on industry which pursues its development of both hardware and software for business use. Firms such as Schlumberger, Texas Instruments and others continue to advance AI and incorporate its principles into their product lines (Mishkoff, 1986). Both academia and private industry have an interest in AI research hearkening back as far as the Dartmouth conference where two of the principal organizers were from academia and two from private industry. Today, AI research is advancing both at universities such as Stanford and MIT as well as in industry and private "think tanks" such as the SRI (Stanford Research Institute) which developed the sophisticated ambulatory robot named Shakey, a mimic of the mythological androids conceived by Vulcan (Mishkoff, 1986).

The history of the development of hardware to perform the software functions discussed is one of steady
progress. The massive circuitry and multitude of vacuum tubes that made up ENIAC were replaced by transistors and integrated circuits enabling the size of machines to be reduced. Today's VLSI (Very Large Scale Integrated) circuits technology allows hundreds of thousands of electronic devices to reside on a single silicon chip. Chips are so complex that no one individual could be the sole designer.

Such chips, no less than the software described herein, provide the power that furthers artificial intelligence development. Microcomputer add-on boards that increase the amount of memory available for working with programs and data, and the advent of laser disks that can hold whole encyclopedias of information on a disk the same size as those used in a PC have placed the computer's capabilities at the fingertips of the individual user. The increasingly interactive abilities of the computer have expanded its functions beyond the realm of data processing and problem solving to the inclusion of decision support functions as will be tested with TPN.COM.

Program Evaluation

The purpose of doing research in pharmacy is to gain knowledge. Indeed, the Study Commission on Pharmacy characterized the profession as a knowledge system. The
application of this knowledge by the practitioner to the restoration or maintenance of health was proclaimed as "the ultimate justification and intrinsic value of the system" (The Millis Commission, 1975). This observation suggests that the knowledge base of the profession must grow if pharmacy is to remain viable.

Need to Evaluate Program

The government has been expanding its contribution to the payment of health services and medical care costs since 1965. Ultimately, spiraling cost, ever increasing demand and finite resources have forced legislative efforts to control medical costs. Changes in hospital reimbursement finances have shifted pharmacy from a proliferating revenue generating department to a high cost service department. Hospital administrators have been forced to stringently weight personnel and resource allocations against the benefits and impacts of departmental programs. Within the profession of pharmacy, managers and leaders are turning to the evaluation of innovative services as a means of justifying the development and implementation of new services (Bootman, McGhan and Schondelmeyer, 1982). The resources available for new programs and even for the maintenance of existing programs are limited. Pharmacists requesting personnel and resources to develop a custom microcomputer application cannot be expected to be funded
unless the program can demonstrate its effectiveness, relevance and benefits relative to incurred costs. Otherwise, it may not survive hospital competition for limited funds.

Research and Evaluation

Program evaluation was long viewed as a form of art, and not pure scientific research (Schulberg and Baker, 1979). In this sense, the word "scientific" is not used to connote disciplined and systematic inquiry, but rather the observation, hypothesis, laboratory controlled experimental model. A general contemporary definition of program evaluation would convey: "a study to assess the worth or merit of a program". A distinction can be made that research seeks to confirm hypotheses about the universal theoretical underpinnings of the nature of phenomena, whereas the results of evaluation are often used for program planning policy and decision making. As such, evaluation results appear limited to a specific real world site, time and situation. The information gained in a field study evaluation is not easily generalized, unless the site, situation, program inputs, process and outcome have been rigorously selected, controlled, and described as an exemplar of the larger universe (Miles and Huberman).
Limitations of the Experimental Design

A number of problems are encountered when attempting to apply the experimental model to program evaluation (Schulberg and Baker, 1979): (1) subjects cannot be randomly assigned to groups; (2) key sources of variance cannot be controlled; (3) intervention and outcome commonly have only theoretical links; and (4) many programs simultaneously employ multiple interventions. Researchers seeking to obviate these problems through highly structured designs may fragment the problems being studied to the extent that the ultimate findings may be irrelevant to programmatic decision making. The use of a strict experimental paradigm focusing on single variables may endorse piecemeal incremental change while ignoring the catalytic or synergistic effects of a major real world undertaking (Schulberg and Baker, 1979).

Uses of Program Evaluation

Program evaluation is a particular type of research enterprise that takes place usually within the real world of organizational environments and its relation to ongoing programmatic commitments. Program evaluations are organized to serve the decision making process at the program level and provide relevant and timely information to management. Purposes and levels of assessment have situational rather than absolute determinants (Schulberg and Baker, 1979). For
example, the purpose of an evaluation can be to assess the appropriateness of program changes, identify ways to improve the delivery of interventions and meet accountability requirements or the focus can be directed at testing innovative ideas on how to deal with problems deciding whether to expand or curtail programs or whether to advocate one program rather than another.

Hypothesis Testing

The purpose of evaluation can also be to test hypotheses or principles. This type of evaluation is particularly suited to the implementation of the developmental stages of an innovative program. The laboratory-controlled empiric design can allow researchers to isolate particular variables and test hypotheses of interest. The key to program evaluation regardless of its paradigm is to design and implement an evaluation that is as objective as possible to provide a firm assessment of the situation (Rossi and Freeman, 1982). The future of the program evaluated may depend on the effectiveness, efficiency and adequacy of the program to achieve stated objectives.

Exploratory Evaluation

Evaluations can be undertaken to provide exploratory evidence of a program's legitimacy and potential
effectiveness in order to provide continued support and guidelines for expansion of the innovative program (Rossi and Freeman, 1982). In one sense, this research project may be perceived as an exploratory research and development cost effective evaluation model. In this instance, a relevant pharmacy task function lending itself to a computer assisted decision support system was identified. A knowledge based decision support system specifically designed to decrease user time, mathematical errors and provide the user with appropriateness recognition channeling and identification of salient information and decision nodes in the strategic domain was developed. The system's (non-distributive task function) objectives were to improve subsequent decisions by both novice and experienced users commensurate with that of expert pharmacists and neonatologists. An empirical study, using an independent groups design was conducted to examine the effects of a decision support system on performance variables of interest, and to specifically test hypotheses. An ideal evaluation strategy would have tested the effect of the program on impact variables of interest, i.e., time, errors, appropriateness, confidence and cost, in a number of real hospital settings.

Rationale for a Laboratory Model

In the case of the TPN.COM program developed in conjunction with this project, the program evaluation was
conducted as a laboratory-controlled experiment rather than as a field study in accordance with a research and development modality. Since the program is intended for use in the medical field as a means of determining quantitative nutritional and drug dosages for human subjects, prudence and medico-legal liability dictated that the program be initially tested in a laboratory-controlled situation rather than as a field trial. Until the accuracy of the program is assured, it would be irresponsible to utilize this program in the field. Therefore, an exploratory laboratory controlled experimental evaluation mimicking the conditions of preparing neonatal hyperalimentation was employed as opposed to testing the program in a hospital setting.

Evaluation Methodologies

A number of techniques can be employed by program evaluators. McGhan et al have discussed the use of cost-benefit analysis, cost-effectiveness analysis and cost-impact analysis techniques in the evaluation of innovative pharmacy services. The following brief definitions are offered:

COST BENEFIT ANALYSIS: Program evaluation technique that summarizes the monetary benefits of the program as an index of the cost of the program. The index is known as a cost benefit ratio.
COST IMPACT ANALYSIS: A program evaluation technique that measures and identifies the costs and selected impacts of interest to the evaluator of a specific program.

COST EFFECTIVE ANALYSIS: A program evaluation technique to provide decision makers with identification and/or quantification of comparative program costs and selected impact measures among two or more program alternatives.

The most commonly used decision making criteria is the cost benefit analysis. In this evaluation methodology, a cost benefit ratio is calculated as the present value of the benefits divided by the present value of the cost. Any ratio greater than one will indicate that the present value of the benefits outweigh the present value of the cost. When alternative projects are mutually exclusive and no budget constraints exist it may be desirable to maximize the benefits by ranking the projects by the amount by which the present value of their benefits exceed the present value of their costs (Prest and Turvey, 1965). All benefits and costs which occur at different times must be adjusted to reflect comparable values. This is accomplished by converting dollar amounts into present values through the use of an interest rate referred to as the discount rate (Klarman, 1965). Quade of the Rand Corporation defines cost effectiveness as a technique: "...designed to assist a
decision maker in identifying a preferred choice among possible alternatives" (Quade, 1967). Crystal and Brewer defined cost effectiveness as "a series of analytical and mathematical procedures which aid in the selection of a course of action from various alternative approaches."

The evaluator's decision to employ a particular technique stems from the emphasis and unit of measure of the input and output criteria. Cost benefit analysis is a mechanism to compare the expected benefits of alternative programs to determine which is the best investment. The emphasis appears to be on the most effective use of money when given a choice of possible programs. Both cost and benefits are expressed in dollars to permit comparisons. In cost effectiveness analysis, costs are calculated and then alternative ways are compared for achieving a specific set of results. The objective is not limited to monetary efficiency but it includes an emphasis on output criteria (Smith, 1968). William Niskanen differentiates between the approaches according to the units for inputs and outputs.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical Operations</td>
<td>Units</td>
<td>Units</td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost/Effectiveness</td>
<td>Dollars</td>
<td>Units</td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost/Benefit Analysis</td>
<td>Dollars</td>
<td>Dollars</td>
</tr>
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<td></td>
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</tbody>
</table>

For example, in operations research, the inputs may
be measured in "hyperalimentation bottles prepared" and the output in "number of mathematical errors", "pharmacy hours", etc. In general, in cost-effectiveness analysis, the outputs are related to various outcome measures such as weight gain, metabolic complications, life-years added, number of errors prevented, etc. Cost-benefit analysis is differentiated from cost-effectiveness analysis through the use of dollars to measure the output of the respective program (Niskanen, 1967).

Prior Studies

An ultimate measure of the impact or utility of an expert system is its effect on real world user performance. The majority of studies on expert systems and decision support systems have neglected to focus on this fact. Artificial intelligence is fundamentally a science of programming. The majority of studies on expert systems have focused on the development process. Authors have related in detail analysis of the problem task, interviewing experts, problem solving and algorithm design and the efficiency and limitations of the programming language to adapt to the unique aspects of the inference engine (Goul, et al, 1986). Studies from the management information systems literature have focused on cognitive models, memory aids and strategic determinants of mimicking human performance. Other management information studies have been concerned with the
user programmer and change agent phenomena in the adoption of decision support applications (McCorduck, 1985). Trade journal articles have focused on innovative programming languages and expert systems development shells. While these articles discuss advantages and limitations of various programming languages, the question of user performance is left unanswered. The impact of these articles is only minimally more useful than commercial advertisements. From a commercial sense if a program is selling it must have utility.

One measure of a program's utility is its widespread application and adoption among users. DENDRAL and PROSPECTOR are certainly examples that fall into this category. Medical decision support systems such as Oncocin, Puff, Mycin, Internist I have not achieved wide-scale commercial adoption. These programs have remained the brain child of artificial intelligence research laboratories associated with university hospital settings. One study appearing in JAMA focused attention on user performance. Internist I out performed individual physicians in diagnosing complicated patient case studies. A panel of expert physicians only slightly out performed the program in a controlled experiment. This study is one of the few that actually compare computer assisted user performance with that of individuals and experts. (McCorduck, 1985)
Use of Computers in Hyperalimentation

Computers are being used with increasing frequency in the delivery of hyperalimentation. Their use is saving physician and pharmacist time in solution ordering and preparation and is also beneficial in clinical and nutritional assessment and diet analysis.

Solution Preparation

Baker et al (1974) described the use of a computer to assist the pharmacy in formulating pediatric hyperalimentation solutions. A computer program for the preparation of tailored hyperalimentation solutions for neonates employing a standardized order sheet for the physicians was reported by May and Robbins (1978). Once ordered, the data was fed into the computer by pharmacy staff to generate a formula for pharmacy use in solution preparation, a label with the bottle contents per fluid volume ordered, and a summary sheet reviewing the patient's nutritional input of the past 24 hours.

Giacoia et al (1980) addressed the issue of saving pharmacy time. Given an average of 350 formulations per month, they reported an annual savings of approximately 900 hours of pharmacist time by using computer-assisted hyperalimentation.
Clinical Monitoring

Although a reduction in manpower is an obvious advantage of using computers, programs have also been developed to store and analyze important clinical data. Sharp and German (1977) developed a program for continuous data processing of the important numerical data used in the monitoring of infants on intravenous nutrition. Following analysis of the data, the computer generated graphs of caloric intake over time and plotted daily weight gain on a growth grid. Fisher and Munro (1980) described a computer program developed to assess and monitor the nutritional status of hospitalized patients. Their program permitted the nutritional assessment of large numbers of patients and also provided detailed evaluations of the efficacy of hyperalimentation. Storage of accumulated data and its subsequent analysis will make it possible to determine the effects of nutritional correction on morbidity and mortality. Some institutions employ computer-assisted diet analysis programs to identify nutrient deficiencies based on input of their patient's daily nutritional intake (Danford, 1981).

Ordering Solutions

Computer technology has much to offer in the provision of hyperalimentation not only in solution
preparation and clinical monitoring, but also in solution ordering based on analysis of important patient variables. Giacoia and Chopra (1980) are using a program to arrive at final hyperalimentation solution orders that take into account the following factors: insensible water loss, normal water loss (e.g., stool, urine); abnormal water loss (e.g., gastric, excessive urine output); surplus of water (e.g., blood transfusions); and carbohydrate, protein, fat, vitamin and trace element requirements. This type of detailed program has been used only for a short period of time but appears to be quite promising.

Hyperalimentation Computer Program Evaluations

Evaluation of computer programs in the field of pharmacy hyperalimentation have been limited to user field studies. Authors have described the purpose of the program, the microcomputer hardware and software employed as input measures, and in some cases the acquisition of the project. None of these evaluations attempted to address the cost of programming. All of the computer programs were developed by in-house hospital personnel (Trudeau, 1984).

Output criteria have focused on time labor savings. The savings of a 0.4 full time pharmacist equivalent at the Richland Memorial Hospital was cited in the introduction. While researchers at Stanford University Hospital and
Richland Memorial Hospital have reported that their computer program aided in the reduction of mathematical errors, neither quantified this benefit.

Some adult hyperalimentation programs have been designed to maintain order and patient information and produce summary database reports. These clinical patient database style reports were placed in the patient chart, and cited by the author as useful to both pharmacists and physicians (Trudeau, 1984). Would this same report be of value to a non-specialty trained pharmacist? The TPN.COM decision support module of the program was designed to aid the novice or non-specialty trained pharmacist to better identify blatant inappropriate neonatal hyperalimentation orders.

Mickey Williamson suggests that a cost benefit analysis be performed prospectively and retrospectively when developing a decision support application. He suggests that the development costs, including the hardware, software, programming and project coordinators time be estimated. Then the estimated salary cost of the time savings derived from the program should be compared.

The cost effective analysis is more suitable to our study since the dollar value of "mathematical errors" or "failure to identify inappropriate order items" is difficult
to quantify. Such measures are included in traditional cost benefit analysis as "intangible benefits". The impact criteria of interest, i.e., time, errors, appropriateness, and confidence, were more suitably measured and reported as units for the purposes of this study.
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Pages 137-164
Part II: The Evaluation

The overall evaluation strategy adopted was a "cost analysis":

<table>
<thead>
<tr>
<th>INPUT:</th>
<th>OUTPUT:</th>
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<tbody>
<tr>
<td>TPN Program Development Cost</td>
<td>Output Criteria</td>
</tr>
</tbody>
</table>

In cost effectiveness analysis, costs are calculated and then alternative ways are compared for achieving a specific set of results. The objective of this, as a cost analysis, was to identify program development costs and to quantify and compare outcome measures.

The program evaluation was undertaken to assess the cost and output criteria of the computer-assisted intervention compared to the traditional manual method commonly used in preparing neonatal hyperalimentation.

The program evaluation phase of the Thesis Project included the following planning and execution:

1. Developing a conceptual framework for the program evaluation.
2. Adopting an evaluation methodology.
3. Methodology
   a. Research design.
   b. Instrument development.
   c. Selection of subject.
   d. Data collection.
   e. Data analysis and Hypotheses Testing.
CONCEPTUAL FRAMEWORK FOR EVALUATION MODEL

The evaluation was conceived as a context-input-process-output model. The following diagram presents a conceptual framework for the program evaluation model:

**Figure 3. Conceptual Framework for the Evaluation Model**

<table>
<thead>
<tr>
<th>Input Data</th>
<th>User</th>
<th>Method</th>
<th>Output Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Order</td>
<td><em>Technicians</em></td>
<td><em>Manual</em></td>
<td>1. Cost</td>
</tr>
<tr>
<td>*Lab Data</td>
<td>*</td>
<td></td>
<td>2. Time</td>
</tr>
<tr>
<td>*Patient</td>
<td>*----------------------</td>
<td><em>---------</em></td>
<td>3. Errors</td>
</tr>
<tr>
<td><em>Parameters</em></td>
<td><em>Pharmacists</em></td>
<td><em>Computer</em></td>
<td>4. Appropriateness</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. Confidence</td>
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<td></td>
<td></td>
<td></td>
<td>6. Importance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>of reviewing orders</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>7. Willingness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>to enter additional input data</td>
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<td></td>
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</tr>
</tbody>
</table>

The context of the study, i.e., its setting and conditions was designed to mimic pharmacy task requirements and conditions in preparing neonatal hyperalimentation.

The input included input data and subject users. The input data was designed as pre-prepared patient information, lab values and mock physician orders. Subjects included technicians and registered pharmacists with
hospital intravenous additive experience.

The process compared traditional manual and the computer-assisted intervention methods for preparing neonatal hyperalimentation.

Output criteria identified in the model were formally defined (see Definitions) and extentionalized as dependent variables. (see Methodology).

**EVALUATION METHODOLOGY**

The evaluation methodology adopted has been described by Bootman, McGhan and Schondelmeyer as a cost effective evaluation:

"COST EFFECTIVE ANALYSIS: A program evaluation technique to provide decision makers with identification and/or quantification of comparative program costs and selected impact measures among two or more program alternatives."

(Bootman, McGhan, and Schondelmeyer, 1982)

The program evaluation technique sought to identify and quantify costs and selected impact measures comparing pharmacist and technician performance in preparing neonatal hyperalimentation, using the traditional manual method and the computer assisted intervention. The intent of the evaluation was descriptive and not intended for decision
making based on some pre-set specified outcome. Rather, the purpose of the evaluation was to examine the performance output criteria of the users as a result of the use of the computer program intervention.

The study design was driven by a concern for exploratory analysis of the computer intervention by scientifically testing specific research hypotheses in a theoretical framework.

The intent of the evaluation program was to advance theoretical knowledge related to the research hypotheses and study objectives in an experimental laboratory-controlled environment, ideally removing site and subject specific confounding variables.

The research design consisted of a randomly assigned, prospective, laboratory-controlled experimental intervention model.

It would be medico-legally negligent to field test the computer intervention prematurely in an actual hospital setting. Thus, the study's aim was exploratory research and avoided problems of patient well-being by using a laboratory-controlled setting. Ideally, theoretical knowledge advanced in the laboratory will advance future practical applications in the field.
Program Development Cost

The program took the author 418 man hours to develop for alpha phase testing. The true cost of the program might include the cost of the Pascal Compiler, paper, diskettes and print ribbons, as well as the authors time. Two experts in computer science (professors in the Computer Science Department) reviewed the program and pointed out that professional programmers charge $25 to $40 an hour. Using $25 per hour as a minimum cost based on 418 man hours the program would be valued at $10,450. However, the author was not a professional programmer. Indeed the author may have taken a great deal longer to develop the program than a professional working with a client. On the other hand the client is charged for analyst time that is merely spent learning exactly what the client requires and planning the program development project. The client is charged for each consultation to analyze and refine the program, in addition to the actual programming. Because the author knew exactly what was required the man hours spent by the author may have been less those charged by a professional programmer. An estimate based on the author's time was considered potentially inaccurate and biased.

Multi_Source Corporation, a small systems development and programming company in Tucson, Arizona, was
engaged to evaluate the TPN program from a software engineering point of view, sophistication, user friendliness, and cost of development. The total development cost was estimated at $9,250 ($2500 analyst fee for 50 hours and $6,750 for 225 man-hours programming cost).

This figure ($9,250) closely approximates the $10,450 estimate based on the author's time. The difference in man-hours probably reflects the author's inexperience.

Research Design

The research design consisted of a prospective laboratory-controlled experimental design. The context of the evaluation consisted of an experimental setting mimicking pharmacy distributive and non-distributive task requirements in the preparation of neonatal hyperalimentation. The alpha phase testing of the TPN program sought to scientifically test research hypotheses related to the computer application intervention. Each of the research hypotheses is stated below in the null form.

Operational Hypotheses

Central Hypothesis: There is no difference in the utility impacts of a custom developed microcomputer program, designed to support distributive and non-distributive pharmacy task functions associated with neonatal hyperalimentation compared to traditional manual methods for
both registered pharmacists and technicians.

The central hypothesis was evaluated in terms of various utility measures. Each hypothesis associated with these measures is stated in the null form:

Hypothesis 1. There is no difference between total computer task time and total manual task time.

Hypothesis 2. There is no difference between computer total task time for pharmacists and computer total task time for technicians.

Hypothesis 3. There is no difference between total computer task time and manual label time.

Hypothesis 4. There is no difference between computer mathematical errors and manual mathematical errors when using the computer program.

Hypothesis 5. There is no difference between pharmacist mathematical errors and technician mathematical errors when using the computer program.

Hypothesis 6. There is no difference between accuracy of computer assisted review of order items for appropriateness and the accuracy of manual review of order items for appropriateness.

Hypothesis 7. There is no difference between accuracy of
pharmacist review of order items for appropriateness and technician review of order items for appropriateness when using the computer program.

Hypothesis 8. There is no difference between computer assisted confidence in determining appropriateness and confidence for manual appropriateness review.

Hypothesis 9. There is no difference between pharmacist confidence in determining appropriateness and technician confidence in determining appropriateness when using the computer.

Hypothesis 10. There is no difference between composite performance for computer assisted appropriateness review and composite performance for manual appropriateness review.

Hypothesis 11. There is no difference between pharmacist composite performance in determining appropriateness and technician composite performance in determining appropriateness when using the computer.

Hypothesis 12. There is no difference between pharmacist perceived importance of responsibility for reviewing order items for appropriateness and that of technicians.

Hypothesis 13. There is no difference between pharmacist's willingness to enter additional input data and that of
Hypothesis 14. There is no correlation between user willingness to enter additional input data and perceived importance of responsibility for reviewing order items for appropriateness.

Setting and Equipment

The experiment was carried out in a well lighted quiet room, free of phone calls, interruptions or other user distractions. The setting provided subjects with seating at a large table to perform their tasks. Subjects performing neonatal hyperalimentation task functions manually were provided: an IBM manual Selectric typewriter, a TI-35 electronic calculator, three sharpened lead pencils, preformatted labels, and a manual worksheet. Subjects performing neonatal hyperalimentation task functions by computer method used an IBM-PC II, with two floppy drives, a 20 megabyte hard disk, dot-matrix printer (print speed 160 characters per second), and a color monitor.

Limitations of the Study Setting

This setting hardly mimics the typical centralized intravenous additive pharmacy, where personnel must perform their tasks in the midst of a noisy, busy production environment with frequent phone calls and interruptions. The distraction free setting was chosen to isolate
confounding variance due to user distraction.

Inputs

The inputs for the study included pharmacist and technician users as subjects. Ten registered pharmacists and ten technicians with intravenous admixture experience in preparing neonatal hyperalimentation were recruited from the southern Arizona area. A flier was prepared and distributed at the University Medical Center and the Tucson Medical Center, sites that prepare neonatal hyperalimentation, to solicit qualified subjects (see Appendix A). Participants were paid a ten dollar honararium as compensation for their participation. Subjects were required to have had training and practical experience in neonatal hyperalimentation preparation. None of the subjects were considered experts specifically in neonatal hyperalimentation, with current job responsibilities devoted to monitoring and consulting on patients in an NICU.

Patient Order Inputs

The test packet instruments, including the patient hyperalimentation information and laboratory data, the manual calculation worksheet, the training sample, the appropriateness/confidence test and questionnaire, were developed to measure subjects' ability to perform distributive and non-distributive pharmacy tasks by manual and computer-assisted method and by technician and registered pharmacist user.
Test Packet Development

The test packet was developed with input from a panel of experts in neonatal hyperalimentation consisting of two board certified neonatologists, two pharmacists and one pediatric gastroenterologist, all having extensive experience and expertise in neonatal hyperalimentation.

Patient Orders

Three patient orders were developed, one to be used as a subject training sample, and two to be used as test orders A and B. Each order included the patient name, date of order, date of birth, weight, a brief diagnosis, laboratory data, and the hyperalimentation order information. (see Appendix B-D) All of the laboratory values are within normal ranges for a 29 week gestation premature infant with respiratory distress syndrome. The sample order was unique from test orders A and B. It was designed solely for subject pre-training. Test orders A and B were designed to be similar. Although the patient names, and numeric values of the order items are slightly different the order items are in the same range and clinically identical. Test orders A and B were designed to contain some inappropriate order items. All of the inappropriate order items are blatantly incorrect for the patient. The anomalous order items are obvious overdoses,
underdoses, or gross contraindications. Each inappropriate item is a common neonatal hyperalimentation ingredient such as dextrose, sodium chloride, or potassium phosphate. There are no items designed to test knowledge of controversial clinical issues or esoteric therapy. Appropriate items are similarly cogent.

Manual Calculation Worksheet

A manual calculation worksheet was developed for use by subjects in this study based on similar worksheets used at the Richland Memorial Hospital, University Hospital San Diego, and the Naval Hospital San Diego. Many hospitals use a calculation worksheet to assist in manually calculating the additive volumes to formulate a neonatal hyperalimentation solution in conjunction with a handheld calculator. The worksheet contains 82 fields to be filled in by the user, requiring 53 calculations. The typical order requires the user to make 165 numeric or operand entries to a handheld calculator. The worksheet (see Appendix E) assists the user by proving a written path for performing calculations. The worksheet speeds the manual process and aids accuracy while providing a logical record of the calculations.

Order Appropriateness and Subject Confidence Questionnaire

A set of twelve questions (see Appendix F "Reviewing Order Items for Appropriateness") were prepared to test
subjects ability to correctly distinguish blatantly inappropriate order items. This set of questions were used for all subjects, using either patient order A or B by computer or by the manual method. Of fifteen questions originally prepared three were discarded when reviewed by a panel of experts comprised of neonatologists, a pediatric gastroenterologist, and two pharmacists with specialized training in neonatal hyperalimentation. Discarded questions were deemed controversial, questionable or esoteric by the panel of experts. The remaining twelve questions agreed upon identify six inappropriate order items and six appropriate order items. Inappropriate items on order A were also inappropriate on order B. Questions: 1) total daily fluid volume; 2) protein load; 3) Osmolarity; 5) total potassium; 10) total phosphate; and 12) total fat; are grossly inappropriate for this one kilogram neonate. Although the exact numbers differ, inappropriate overdoses, underdoses and contraindications are mirrored for order A and B. Order A and B appear as unique patients with different lab values and orders. However, they were designed to be clinically indistinguishable, having very similar clinical problems and laboratory values. The subjects were not told that patient order A and patient order B were similar. They were told there may be errors in the orders.
Response to these questions were limited to a selection of appropriate or inappropriate. Each question was followed by a measurement of the subject's confidence in correctly determining the appropriateness of the order item. Subjects were not informed that half of the items were inappropriate. It was expected that if subjects guessed they would average six correct answers. A complete guess would have a 50% chance of being correct. Accordingly the scale for confidence was constructed from 50% for a complete guess to 100% for complete confidence. Subjects were told to rate their confidence that their determination of appropriateness was correct as 50% for a complete guess, and a higher amount based on their knowledge and experience up to a maximum of 100% for complete certainty.

Procedures: Study Coordinator

The study coordinator recorded years of experience for each subject, recorded the subjects test packet according to the random assignment sheet, performed the pre-training session, and acted as a data collector. Subjects were told the purpose of the study was to "evaluate the performance of a computer program compared to traditional manual methods for distributive and non-distributive pharmacy tasks in preparing a neonatal hyperalimentation solution". The study coordinator remained in the room
alone with the subject as an observer to time the subjects, but did not talk to the subject other than to give directions and clarify questions at the beginning of each subject task. At the conclusion of the experiment the coordinator thanked the subject and paid him/her a $10.00 fee. Subjects were requested not to discuss the experiment with other subject candidates.

Random Assignment

Ten technicians and ten pharmacists participated in the study. Each subject performed manual tasks followed by a session of computer tasks. One half of the users, i.e. technicians and pharmacists subjects were randomly assigned to use order A for the manual test and Order B for the computer test, while the other half used order B for the manual test and order A for the computer test.

Two lists of random numbers from one to ten were generated for the assignment of technician and pharmacist test packets. Two lists of random numbers from one to two were generated and matched to the first lists. The random numbers were generated by a random number program from the TURBO PASCAL LIBRARY by Borland International on a microcomputer. The list of numbers one and two were used to assign the subject to receive order A first followed by order B for a one, or to receive order B first followed by order A for a 2:
Table 4. Random Assignment Chart

Technicians:
Entry Number: 9 5 2 3 4 1 6 8 7 10
Test Packet : B B A A A B A B B A

Pharmacists:
Entry Number: 3 5 4 1 7 8 2 6 10 9
Test Packet : A B B B A A A B B A

Subjects were assigned to the next number on the technician or pharmacist list until a total of 20 subjects were tested.

Pre-Training

All subjects received a manual training session administered by the study coordinator, using the sample order, sample label, and a completed worksheet, prior to administering the manual test to familiarize subjects with the use of the typewriter, labels, worksheet, and order format. The manual training session lasted less than ten minutes.

After completing the manual test subjects received pre-training on the computer to gain a reasonable understanding of the use of the program and the instruments using the sample training order. The computer pre-training session lasted less than ten minutes.

The time required for subjects to complete the entire study, including introduction, pre-training, testing and debriefing lasted approximately 45 to 60 minutes per subject.
Manual Tasks

All subjects were required to prepare a manually typed fat emulsion and TPN label, using an IBM Selectric typewriter and pre-formatted labels (see Appendix G) under timed conditions from the first study order. They were then required to fill out the manual calculation worksheet. These steps were timed by the study coordinator. Subjects were then required to complete the appropriateness/confidence questionnaire.

Computer Assisted Method

Subjects were next required to input the second order into the computer and generate labels, mixing instructions, and a clinical report. Each phase of the above tasks was timed by the coordinator. Subjects were then required to complete the Appropriateness/Confidence questionnaire. Subjects reviewing order items for appropriateness and rating their confidence in their determination were assisted in their decision making by the computerized clinical report.

Attitudinal Questionnaire

Subjects were next asked to answer two additional attitudinal questions measuring subjects' personal perception of the importance of pharmacy to check order items for appropriateness and subjects' willingness to enter
additional laboratory input data on a routine basis in order to obtain a more sophisticated in-depth clinical report. (see Appendix H)

Operational Definitions and Extentionalization of Variables

The research design included the following dependent variables (see Chapter 1 - definition of terms):

**Dependent Variables**

**Total Task Time**

**Label Time**

**Mathematical Error**

**Accuracy of Appropriateness**

**Confidence in Decisions**

**Composite Performance**

**Importance of Determining Appropriateness**

**Willingness to Enter**

**Measurement**

The measurement of each of these dependent variables was judged to be of a continuous or interval level.

**Independent Variables**

Independent variables included input and process factors:

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHOD</td>
<td>Computer vs. Manual</td>
</tr>
<tr>
<td>USER</td>
<td>Technician vs. Pharmacist</td>
</tr>
<tr>
<td>ORDER</td>
<td>Order A vs. Order B (Test Packet)</td>
</tr>
</tbody>
</table>

Years of intravenous admixture experience was also collected.
Data Collection

Data for independent and dependent variables were collected by the study coordinator. Intravenous additive experience was recorded in years. Timed data for the various tasks was recorded using a Casio calculator watch in minutes and seconds. Seconds were converted to decimal values of a minute. Mathematical errors were scored if a numeric value for the addition of a particular ingredient resulted in less than or greater than five percent of the correct amount required. This obviated minor inconsequential errors due to subjects incorrectly rounding values. Appropriateness was collected as the number of correct answers, with a minimum score of zero and a maximum score of twelve. Confidence was collected as the average confidence for the twelve appropriateness questions. Composite performance was scored by summing the confidence for correctly answered appropriateness questions as positive and incorrectly answered questions as negative. The scoring systems conceivably ranged from minus 1200 for a subject who was always 100% confident and always incorrect to plus 1200 for a subject who was always 100% confident and always correct. Attitudinal responses were collected as a seven point likert scale interval level measurement.

All of the recorded data was typed into an ASCII text file on a microcomputer with subject records as rows and variable data in columns.
Statistical Analysis

The raw data text file was read into a statistics data file for subsequent analysis using SYSTAT version 3.0, Systat, Inc. copyright 1985.

Exploratory and Descriptive Data Analysis

Initial data analysis employed descriptive statistical techniques.

Means and standard deviations for Manual versus Computer dependent variables were performed for: 1) the entire group of subjects; 2) by User level; and 3) by Order level.

Means, and standard deviations for number of years of intravenous additive experience was determined for: all subjects; by user (pharmacists versus technicians); by order (order A versus order B); and for the sublevels of user by order. Random assignment of pharmacists and technicians to receive order A or order B provides one method of minimising differences in confounding factors (such as years of experience) accross test groups. Years of experience was retrospectively compared for the test groups to insure internal validity. A two-way analysis of variance was employed to compare years of experience by user and order to determine if differences existed between these subject groups.
A Pearson correlation matrix was performed for the entire data set for exploratory and descriptive purposes.

Hypothesis Testing

Statistical analysis was performed to test each hypothesis. Hypotheses 1 was tested by comparing mean computer total task time with the mean manual total task time and using a paired Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 2 was tested by computing the mean computer total task time for pharmacists and comparing that to the mean manual total task time for technicians and using a Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypotheses 3 was tested by comparing mean computer total task time with mean manual label task time and using an dependent Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypotheses 4 was tested by comparing mean computer mathematical error with mean manual mathematical error and using a paired Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.
Hypothesis 5 was tested by computing the mean mathematical error for pharmacists and comparing that to the mean mathematical error for technicians and using a Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypotheses 6 was tested by comparing mean accuracy of computer assisted review of order items for appropriateness with manual accuracy of review of order items for appropriateness and using a paired Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 7 was tested by computing the mean accuracy of pharmacist review of order items for appropriateness and technician review of order items for appropriateness when using the computer program and comparing the two means using an independent Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypotheses 8 was tested by comparing mean computer assisted confidence in determining appropriateness with mean manual confidence in determining appropriateness and using a paired Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.
Hypothesis 9 was tested by computing the mean pharmacist confidence in determining appropriateness when using the computer and comparing that to the mean technician confidence in determining appropriateness when using the computer and using an independent Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 10 was tested by computing the mean composite performance for computer assisted appropriateness review and the mean composite performance for manual appropriateness review and using a paired Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 11 was tested by computing the mean pharmacist composite performance in determining appropriateness and the mean technician composite performance in determining appropriateness when using the computer and using an independent Student t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 12 was tested by computing the mean pharmacist perceived importance of responsibility for reviewing order items for appropriateness and technicians perceived importance of responsibility for reviewing order items for appropriateness and using an independent Student
t-test to determine if a significant difference existed between the two means at the .05 alpha level.

Hypothesis 13 was tested by computing the mean pharmacists' willingness to enter additional input data and technicians' willingness to enter additional input data and using an independent Student t-test to determine if a significant difference existed between the two means at the

Hypothesis 14 was tested by determining if the pearson correlation coefficient between user willingness to enter additional input data and perceived importance of responsibility for reviewing order items for appropriateness was significant at a 0.05 alpha level.
CHAPTER 4

RESULTS

A microcomputer program, "TPN", designed to assist pharmacy personnel in distributive and non-distributive pharmacy task functions in the preparation of neonatal hyperalimentation was developed and evaluated employing a cost analysis evaluation model.

Cost

The program required 418 man-hours for the author, a non-professional programmer to develop to an alpha phase test level. Using $25 as a minimum hourly rate and 418 man-hours the program was initially valued at $10,450.

Multi_Source Corporation, a small systems development and programming company in Tucson, Arizona, was engaged to evaluate the TPN program from a software engineering point of view, sophistication, user friendliness, and cost of development. The total development cost was estimated at $9,250, $2500 analyst fee for 50 hours and $6,750 for 225 man-hours programming cost (See Appendix I).

Alpha Phase Test Results

The evaluation proceeded to alpha phase testing during the month of June, 1987, at the University of Arizona, College of Pharmacy, Tucson, Arizona.
Ten registered pharmacists and ten technicians from the Tucson, Arizona area, all with intravenous additive experience in the preparation of neonatal hyperalimentation participated in the study. Each subject, required 45 to 60 minutes for enrollment, pre-training, testing, and debriefing. After debriefing subjects received a ten dollar compensation for their participation in the study.

Data Collection and Descriptive Statistics

Raw data for independent and dependent variables for each subject were collected in a record file for analysis. Descriptive statistics, i.e. means and standard deviations, for each variable measure was computed. The raw data and initial descriptive statistics for the entire study appear in Appendix J.

Correlation Matrix

A pearson correlation matrix was computed for the entire study including all independent and dependent variable measures for descriptive purposes. The correlation matrix is included in Appendix K. Pearson r values equal to or greater than 0.444 indicate an association between variables at the 0.05 level.

Order and user are discretely dichotomous variables. A point biserial correlation is the appropriate correlation measure between one of these variables and any of the continuous variables. A Phi-coefficient would be the
suitable measure between order and user where both variables are discretely dichotomous. While the pearson correlation value of \( r \) is a close approximation, to the point biserial and Phi-coefficient, it is not correct and may over or under-estimate the measure of association. Pearson values of \( r \) were computed for these variables and included in the pearson correlation matrix simply to include these variables as part of the entire numeric study index and to provide a rough approximation of their measure of association to other variables.

Subject Demographics

The number of years of intravenous additive experience was collected for pharmacists and technicians. Means, minimum, maximum and standard deviations for all subjects, by user, by order and for the subgroups order by user were computed. These values are delineated in Table 5.

A two way analysis of variance was employed comparing mean years of experience with respect to user, order and the interaction of user by order. The subgroups contained equal sample sizes and the results of both a Bartlett's Test and an F Test indicated homogeneity of group variances.

Differences in mean years of experience were not found to be significant at the 0.05 alpha level for user, i.e. pharmacists versus technicians, nor for order, i.e.
performing manually test packet Order A versus test packet Order B, or the interaction of user by order. Further, the squared multiple $r$ was 0.04, implying little variation between study group means for years of experience. (See Table 5).
Table 5. Two Way Analysis of Variance Comparing Mean Years of Experience by User (Pharmacist vs. Technician) and by Order (Order A vs. Order B) and the Interaction of Experience and Order.

<table>
<thead>
<tr>
<th>ORDER</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHARMACIST</td>
<td>N 5</td>
<td>N 5</td>
<td>N 10</td>
<td></td>
</tr>
<tr>
<td>MIN</td>
<td>0.250</td>
<td>MIN 1.000</td>
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<tr>
<td>MAX</td>
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<td>MAX 5.500</td>
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<tr>
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<td>MEAN 2.734</td>
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<td>S.D.</td>
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<td>S.D. 2.106</td>
<td>S.D. 1.820</td>
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</tr>
<tr>
<td>TECHNICIAN</td>
<td>N 5</td>
<td>N 5</td>
<td>N 10</td>
<td></td>
</tr>
<tr>
<td>MIN</td>
<td>0.500</td>
<td>MIN 1.500</td>
<td>MIN 0.500</td>
<td></td>
</tr>
<tr>
<td>MAX</td>
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<td>MAX 2.500</td>
<td>MAX 5.000</td>
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</tr>
<tr>
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<td>MEAN 2.400</td>
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<tr>
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<td>1.956</td>
<td>S.D. 0.354</td>
<td>S.D. 1.390</td>
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</tr>
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</table>

BARTLETT TEST FOR HOMOGENEITY OF GROUP VARIANCES = 9.331
APPROXIMATE F = 2.852

ANALYSIS OF VARIANCE

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<th>P</th>
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<td>0.443</td>
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<tr>
<td>USER</td>
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<td></td>
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</tr>
<tr>
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<td>45.245</td>
<td>16</td>
<td>2.828</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DEP VAR: YR. N:20  MULTIPLE R:.209  SQUARED MULTIPLE R:.044
Dependent Outcome Criteria

Raw data collection and descriptive statistics, i.e. mean and standard deviation were computed for each of the outcome criteria dependent variables of interest. The mean score for each dependent variable for all subjects, i.e. pharmacist and technicians, are computed comparing computer versus manual method. Study outcome criteria results for distributive and non-distributive pharmacy tasks in preparing neonatal hyperalimentation are presented in the following tables 6 through 10.

Distributive Outcome Results

Table 6 displays raw data for each subject for total task time and total label time. Mean manual total task time for all subjects was 22.57 minutes. Mean computer total task time for all subjects was 6.62 minutes. Mean time to prepare a label manually for all subjects was 7.58 minutes compared to 5.14 minutes to prepare a label using the computer.

Table 7 displays raw data for each subject and the mean manual mathematical error. Mathematical error for all subjects using the computer was zero. Mean mathematical error for all subjects completing the mathematical task by manual method was 2.47 errors.
Table 6. RAW DATA COLLECTION TABLE AND DESCRIPTIVE STATISTICS: TIME (TOTAL TASK TIME and LABEL TIME)

<table>
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<th>Study Num</th>
<th>Subject</th>
<th>{Ind.Var..}</th>
<th>{Dependent Variables..}</th>
</tr>
</thead>
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<td>ORD USR YRS</td>
<td>TIMET(1-2) TIMETL(1-2)</td>
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<td>1 1 1.00</td>
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</tr>
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<td>8</td>
<td>2 1 4.50</td>
<td>6.15 20.80 5.07 5.98</td>
</tr>
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<td>2109</td>
<td>9</td>
<td>2 1 5.50</td>
<td>7.25 26.35 6.00 9.75</td>
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<td>2110</td>
<td>10</td>
<td>2 1 1.17</td>
<td>6.05 29.16 4.61 11.38</td>
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<td>1 2 4.00</td>
<td>4.51 19.40 3.40 5.38</td>
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<td>1212</td>
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VARIABLE KEY:

{ Independent Variables................................. }

ORD  =Order: physician ORDer assigned for manual task (then opposite order by cpu): A=1, B=2
USR  =User: Pharmacist=1, Technician=2
YRS  =Years: i.v. additive experience

{ Dependent Repeated Measures 1=Computer, 2=Manual }

TIMET(1-2)  =Total Task Time
TIMETL(1-2) =Label Time
Table 7. RAW DATA COLLECTION TABLE AND DESCRIPTIVE STATISTICS: ERROR (MATHEMATICAL)

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<tr>
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| MEAN | 2.47 | 0 | 1.55 |
| STANDARD DEVIATION | 1.58 | 0 | 1.85 |

VARIABLE KEY:

{ Independent Variables ......................... }
ORD -physician Order assigned for manual task
   (then opposite order by cpu): A=1, B=2
USR -User: Pharmacist=1, Technician=2
YRS -Years i.v. additive experience

{ Dependent Repeated Measures 1=Computer, 2=Manual }
ERROR(1-2) -Mathematical Errors
Non-Distributive Outcome Results

Table 8 displays raw data for each subject and the manual versus computer mean score for appropriateness and for confidence. Mean appropriateness score for all subjects reviewing orders manually, i.e. without computer decision support, was 6.75 and their mean confidence on a scale of 50 to 100 percent was 65.33. Mean appropriateness score for all subjects reviewing orders with computer decision support was 11.65 and their mean confidence on a scale of 50 to 100 percent was 90.40.

Table 9 displays raw data for each subject and manual versus computer mean scores for composite performance. Mean composite performance score for all subjects reviewing orders manually, i.e. without computer decision support, was 152 compared to a mean composite performance score of 1035.75 for all subjects reviewing orders with computer assisted decision support.

Table 10 displays raw data as seven point likert scale scores for each subject for importance of reviewing and willingness to enter additional data. Mean importance of reviewing was 6.65, while mean willingness to enter additional laboratory data into the computer as a routine task was 6.00. Mean subject response to each of these questions was strong to very strongly favorable.
Table 8. RAW DATA COLLECTION TABLE
AND
DESCRIPTIVE STATISTICS:
APPROPRIATENESS and CONFIDENCE

<table>
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<th>(-Dependent Variables..)</th>
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</table>

MEAN  2.47  11.65  6.75  90.40  65.33
STANDARD DEVIATION  1.58  0.67  1.16  7.24  9.64

VARIABLE KEY:

{ Independent Variables..................................................}

ORD  -physician Order assigned for manual
task (opposite order by cpu): A=1, B=2
USR  -User: Pharmacist=1, Technician=2
YRS  -Years i.v. additive experience

{ Dependent Repeated Measures  1=Computer,  2=Manual  }

APPRO(1-2)  -Appropriateness
CONF(1-2)   -Confidence
Table 9. RAW DATA COLLECTION TABLE AND DESCRIPTIVE STATISTICS: COMPOSITE PERFORMANCE

<table>
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</thead>
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**MEAN**  
2.47  1035.75  152.00

**STANDARD DEVIATION**  
1.58  150.63  168.07

VARIABLE KEY:

(Independent Variables).................................

- **ORD** - physician Order assigned for manual task  
  (then opposite order by cpu): A=1, B=2
- **USR** - User: Pharmacist=1, Technician=2
- **YRS** - Years i.v. additive experience

(Dependent Repeated Measures  1=Computer, 2=Manual )

**COMPOS(1-2)** - Composite Performance
Table 10. RAW DATA COLLECTION TABLE
AND
DESCRIPTIVE STATISTICS:
IMPORTANCE OF REVIEWING
and
WILLINGNESS TO ENTER

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<th>{Dependent Variables..}</th>
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| MEAN | 2.47 | 6.65 | 6.00 |
| STANDARD DEVIATION | 1.58 | 0.49 | 0.72 |

VARIABLE KEY:

{ Independent Variables.................................}

ORD -physician Order assigned for manual task
     (then opposite order by cpu): A=1, B=2
USR -User: Pharmacist=1, Technician=2
YRS -Years i.v. additive experience

{ Dependent Repeated Measures 1=Computer, 2=Manual }

IMPREV -Importance of Reviewing
WILENT -Willingness to Enter
Hypothesis Testing

The Central Hypothesis stated there is no difference in the utility impacts of a custom developed microcomputer program, designed to support distributive and non-distributive pharmacy task functions associated with neonatal hyperalimentation compared to traditional manual methods for both registered pharmacists and technicians. The central hypothesis was evaluated in terms of various utility measures. Statistical analysis was performed to test each hypothesis associated with these measures.

Table 11 displays the results of Student dependent t-tests for significance in difference of means between manual and computer assisted outcome criteria for total task time, label time, error, appropriateness, confidence and composite performance. Table 12 displays the results of Student independent t-tests for significance in difference of means between technician and pharmacists for manual and computer assisted outcome criteria for total task time, label time, error, appropriateness, confidence and composite performance.

Hypothesis 1 stated there is no difference between total computer task time and total manual task time. Hypotheses 1 was tested by comparing mean computer total task time (6.620 minutes) with the mean manual total task time (22.57 minutes) and using a paired Student t-test to determine if a significant difference existed between the
two means at the 0.05 alpha level. The null hypothesis was rejected since the mean computer total task time was significantly smaller than the mean manual total task time. \( t=16.947, \ df=19, \ p<.001, \) See Table 11. \)

Hypothesis 2 stated there is no difference between computer total task time for pharmacists and computer total task time for technicians. Hypothesis 2 was tested by computing the mean computer total task time for pharmacists (6.798 minutes) and comparing that to the mean computer total task time for technicians (6.442 minutes) and using a Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was not rejected since the mean computer total task time for pharmacists was not significantly different than the mean computer total task time for technicians. \( t=.744, \ df=18, \ p=.466, \) See Table 12. \)

Hypothesis 3 stated there is no difference between total computer task time and manual label time. Hypotheses 3 was tested by comparing mean computer total task time (6.620 minutes) with the mean manual label task time (7.58 minutes) and using an dependent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level \( t=1.689, \ df=19, \ p=.108 \). The null hypothesis was not rejected since the total computer task
time was not significantly different than the mean manual total task time at the 0.05 level. (See Table 11.)

Hypothesis 4 stated that there is no difference between computer mathematical error and manual mathematical error when using the computer program. Hypotheses 4 was tested by comparing mean computer mathematical error for all subjects (zero) with mean manual mathematical error (1.55 errors) and using a paired Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was rejected since the mean computer mathematical error was significantly less than the mean manual mathematical error. (t=3.749, df=19, p=.001, See Table 11.)

Hypothesis 5 stated that there is no difference between pharmacist mathematical errors and technician mathematical errors when using the computer program. Hypothesis 5 was not tested because mathematical error for all subjects when using the computer, pharmacists and technicians, was zero, i.e. there was no sample variation. The null hypothesis was not rejected. (See Table 12.)

Hypothesis 6 stated that there is no difference between accuracy of computer assisted review of order items for appropriateness and the accuracy of manual review of order items for appropriateness. Hypotheses 6 was tested by comparing mean accuracy of computer assisted review of order items for appropriateness (11.65) with manual accuracy of
review of order items for appropriateness (6.75) and using a paired Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was rejected since the mean accuracy of computer assisted review of order items for appropriateness was significantly higher than the mean manual accuracy of review of order items for appropriateness at the 0.05 level. (t=19.579, df= 19, p<.001, See Table 11.)

Hypothesis 7 stated that there is no difference between accuracy of pharmacist review of order items for appropriateness and technician review of order items for appropriateness when using the computer program. Hypothesis 7 was tested by computing the mean accuracy of pharmacist review of order items for appropriateness (11.9) and technician review of order items for appropriateness (11.4) when using the computer program and comparing the two means using an independent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was not rejected since the accuracy of pharmacist review of order items for appropriateness and technician review of order items for appropriateness when using the computer program was not significantly different at the 0.05 level. (t=1.756, df=18, p=.096, See Table 12.)
Hypothesis 8 stated that there is no difference between computer assisted confidence in determining appropriateness and manual confidence in determining appropriateness. Hypotheses 8 was tested by comparing mean computer assisted confidence in determining appropriateness (90.397%) with mean manual confidence in determining appropriateness (65.328%) and using a paired Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was rejected since the mean computer assisted confidence in determining appropriateness was significantly higher than the mean manual confidence in determining appropriateness at the 0.05 level. (t=11.716, df= 19, p<.001, See Table 11.)

Hypothesis 9 stated there is no difference between pharmacist confidence in determining appropriateness and technician confidence in determining appropriateness when using the computer. Hypothesis 9 was tested by computing the mean pharmacist confidence in determining appropriateness (93.416%) when using the computer and comparing that to the mean technician confidence in determining appropriateness when using the computer (87.377%) and using an independent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was not rejected since the mean pharmacist confidence in determining appropriateness when using the computer was not
significantly different than the mean technician confidence in determining appropriateness when using the computer at the 0.05 level. (t=2.010, df=18, p=.060, See table 12.)

Hypothesis 10 stated that there is no difference between composite performance for computer assisted appropriateness review and composite performance for manual appropriateness review. Hypothesis 10 was tested by computing the mean composite performance for computer assisted appropriateness review (1035.70) and the mean composite performance for manual appropriateness review (152) and using a paired Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was rejected since the mean composite performance for computer assisted appropriateness review was significantly higher than the mean composite performance for manual appropriateness review at the 0.05 level. (t=19.012, df=19, p<.001, See Table 11.)

Hypothesis 11 stated that there is no difference between pharmacist composite performance in determining appropriateness and technician composite performance in determining appropriateness when using the computer. Hypothesis 11 was tested by computing the mean pharmacist composite performance in determining appropriateness (272.5) and technician composite performance in determining appropriateness (31.5) when using the computer and using an
independent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was rejected since the pharmacist composite performance in determining appropriateness was significantly higher than the technician composite performance in determining appropriateness when using the computer at the 0.05 level. (t=2.145, df=18, p=.046, See Table 12.)

Hypothesis 12 stated that there is no difference between pharmacist perceived importance of responsibility for reviewing order items for appropriateness and that of technicians. Hypothesis 12 was tested by computing the mean pharmacist perceived importance of responsibility for reviewing order items for appropriateness (6.6, very strongly) and technicians perceived importance of responsibility for reviewing order items for appropriateness (6.7, very strongly) and using an independent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was not rejected since pharmacist's perceived importance of responsibility for reviewing order items for appropriateness was not significantly different than technician's perceived importance of responsibility for reviewing order items for appropriateness at the 0.05 level. (t=.447, df=18, p=.660, See Table 12.)
Hypothesis 13 stated that there is no difference between pharmacists' willingness to enter additional input data and that of technicians. Hypothesis 13 was tested by computing the mean pharmacist's willingness to enter additional input data (6.3, very strongly willing) and technician's willingness to enter additional input data (5.7, very strongly willing) and using an independent Student t-test to determine if a significant difference existed between the two means at the 0.05 alpha level. The null hypothesis was not rejected since mean pharmacists willingness to enter additional data was not significantly different than mean technician willingness to enter additional data at the 0.05 level. (t=1.988, df=18, p=.062, See Table 12.)

Hypothesis 14 stated that there is no correlation between user willingness to enter additional input data and perceived importance of responsibility for reviewing order items for appropriateness. Hypothesis 14 was tested by determining if the pearson correlation coefficient between user willingness to enter additional input data and perceived importance of responsibility for reviewing order items for appropriateness was significant at the 0.05 level. The null hypothesis was not rejected since the Pearson correlation value (r = 0.296, df=18) was not significant at the 0.05 level. (See Appendix K)
Table 11. Student dependent t-test for significance in difference of means between manual and computer assisted outcome criteria for total task time, label time, error, appropriateness, confidence and composite performance.

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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>degrees of freedom = 19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All tests were significant at the 0.05 level.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Table 12. Student independent t-test for significance in difference of means between technician and pharmacists for manual and computer assisted outcome criteria for total task time, label time, error, appropriateness, confidence and composite performance.

<table>
<thead>
<tr>
<th></th>
<th>Technicians (N=10)</th>
<th>Pharmacists (N=10)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
<td>S.D.</td>
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<tr>
<td>Total Task Time (Computer)</td>
<td>6.442</td>
<td>1.313</td>
<td>6.798</td>
<td>0.752</td>
</tr>
<tr>
<td>Label Time (Manual)</td>
<td>7.447</td>
<td>2.563</td>
<td>7.713</td>
<td>1.860</td>
</tr>
<tr>
<td>Label Time (Computer)</td>
<td>5.025</td>
<td>1.215</td>
<td>5.259</td>
<td>0.995</td>
</tr>
<tr>
<td>Error (manual)</td>
<td>2.200</td>
<td>2.098</td>
<td>0.900</td>
<td>1.370</td>
</tr>
<tr>
<td>Error (computer)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Appropriateness (manual)</td>
<td>6.200</td>
<td>0.798</td>
<td>7.300</td>
<td>1.252</td>
</tr>
<tr>
<td>Appropriateness (computer)</td>
<td>11.400</td>
<td>0.843</td>
<td>11.900</td>
<td>0.316</td>
</tr>
<tr>
<td>Confidence (manual)</td>
<td>61.791</td>
<td>10.308</td>
<td>68.865</td>
<td>7.871</td>
</tr>
<tr>
<td>Confidence (computer)</td>
<td>87.377</td>
<td>8.960</td>
<td>93.416</td>
<td>3.160</td>
</tr>
<tr>
<td>Composite Performance (manual)</td>
<td>31.500</td>
<td>115.712</td>
<td>272.500</td>
<td>118.21</td>
</tr>
<tr>
<td>Composite Performance (computer)</td>
<td>969.500</td>
<td>180.654</td>
<td>1102.00</td>
<td>74.244</td>
</tr>
<tr>
<td>Importance of Reviewing</td>
<td>6.700</td>
<td>.483</td>
<td>6.600</td>
<td>.516</td>
</tr>
<tr>
<td>Willingness to Enter</td>
<td>5.700</td>
<td>.675</td>
<td>6.300</td>
<td>.675</td>
</tr>
</tbody>
</table>

Notes:
degrees of freedom = 18
* significant at the 0.05 level.
! insufficient data for analysis (data set has no variance)
CHAPTER 5
DISCUSSION, CONCLUSIONS
AND
RECOMMENDATIONS

This chapter summarizes and discusses the results of this study and some incidental findings of interest, draws some conclusions about those results, and makes some recommendations for the use of decision support systems in pharmacy, future studies and education.

A microcomputer program, "TPN", designed to assist pharmacy personnel in distributive and non-distributive pharmacy task functions in the preparation of neonatal hyperalimentation was developed and evaluated employing a cost analysis evaluation model.

The program evaluation technique identified costs and quantified selected impact measures comparing pharmacist and technician performance in preparing neonatal hyperalimentation, using the traditional manual method and the computer assisted intervention. The intent of the evaluation was descriptive and not intended for decision making based on some pre-set specified outcome. Rather, the purpose of evaluation was to examine the performance output criteria of the users as a result of the use of the computer program intervention.
Generalization of Results

The study design was driven by a concern for exploratory analysis of the computer intervention by scientifically testing specific research hypotheses in a theoretical framework. The reader is first and foremost cautioned that the knowledge gained by the results of this research project cannot be generalized beyond the scope and limitations of the study. The major limitation to generalization is the problem of representativeness. There are a number of limitations that have been referred to that deserve further discussion.

The intent of the evaluation program was to advance theoretical knowledge related to the research hypotheses and study objectives in an experimental laboratory-controlled environment, ideally removing site and subject specific confounding variables. Ethical considerations precluded testing the program prematurely in an actual hospital setting. The study’s aim was exploratory research and avoided problems of patient well-being by using a laboratory-controlled setting. The results may have been quite different in an actual busy hospital pharmacy, with hand written physician orders, ringing phones and distractions. Therefore the results may not be representative of actual hospital pharmacy practice.

The research design consisted of a randomly assigned, prospective, laboratory-controlled experimental
intervention model. Generalization of the results is limited by the representativeness of the subject sample. Subjects were not randomly selected. They consisted of a small number of paid volunteers, who met the study subject criteria from the only two hospitals in the Tucson, Arizona area that provide neonatal hyperalimentation. Therefore, the sample is not a random selection, representative of a larger population.

Despite these limitations, the author would suggest that the subjects are fairly typical of non-specialist trained hospital pharmacists and technicians tasked with preparing neonatal hyperalimentation solutions. All of the subjects were non-specialist, with work experience in preparing neonatal hyperalimentation. There is no reason to expect that these subjects would perform differently from other similarly qualified volunteer subjects, draw from similar hospital settings. To this extent the results of this study can be extended. Ideally, theoretical knowledge advanced in the laboratory, i.e. alpha phase testing under controlled conditions, will advance future practical applications in the field. With the aforementioned limitations stated a discussion of the results and findings of this study follow.
Discussion of Findings

Distributive Utility Measures

The TPN program was designed to assist users in performing both distributive and non-distributive pharmacy tasks in preparing neonatal hyperalimentation. The major objective of the study was to evaluate the utility of a custom designed microcomputer application by performing a cost analysis evaluation to identify program development costs and to compare pharmacy utility impact measures between computer assisted and traditional manual methods, by level of subject experience, i.e., pharmacist versus technician user.

Pharmacy distributive performance goals are committed to accuracy and efficiency. The TPN program was specifically designed to decrease the task time associated with label generation, calculating mixing instructions, and to reduce the number of mathematical errors. Each of these utility measures were vastly improved by the computer assisted intervention.

Ryan et al, 1986, reported that a neonatal hyperalimentation solution was the single most time consuming work unit accounting for 49 minutes of preparation time. In the alpha test study subjects did not physically prepare the solution. Manual label creation and calculations using an electric typewriter, pre-formatted labels, a calculation worksheet and a handheld calculator
required 22.568 minutes. There was no difference between pharmacists and technician manual total task time. Total task time was reduced by 16.948 minutes using the computer. Thomas, 1986, similarly reported a labor savings of 9 minutes per bottle by adopting a computer program to generate labels and mixing instructions. In the alpha test study there was no difference between pharmacists and technicians when using the computer. These results would indicate that manual label preparation and calculations are tedious time consuming requirements regardless of level of education and that computerization greatly decreases task time for pharmacists or technicians.

The goal of distributive accuracy was assessed by comparing the number of mathematical errors committed manually and when using the computer. Subjects committed 1.55 errors using a worksheet and a hand held calculator. Pharmacists committed 0.9 errors compared to 2.2 for technicians, but this difference (p = .118) was not significantly different at the 0.05 level. There were no errors for subjects using the computer.

The propensity of hospital staff to make mathematical errors in the preparation of pediatric doses has been demonstrated for physicians, nurses and pharmacists (Koren et al, 1983). Koren's study indicated that experienced professionals were as likely to make mathematical errors as
inexperienced professionals. The Richland Memorial Hospital reported a reduction in mathematical errors after adopting a computer program for neonatal hyperalimentation preparation. The results of the alpha test indicate that most of the manual errors were due to mundane human errors such as transposing numbers, and transcription mistakes regardless of subject professional education, and that using the computer greatly decreased errors.

The utility of a computer application is derived from having the computer create a file and automatically calculate and generate several reports from a single input procedure mimicking an original manual task (Joseph, 1982). Typing patient order information onto a pre-printed formatted label on a typewriter was mimicked by the input screen of the computer program. Therefore, the labor required to type a label becomes the input procedure to the computer program. An ideally efficient program would be capable of supplying labels, mixing instructions and a clinical report all from a single efficient input procedure.

The efficiency of this principal was demonstrated by comparing the manual label time with computer total task time. Subjects required 7.58 minutes to type the Fat and TPN labels on an electric typewriter, using a pre-printed formatted label. Using the computer subjects took 6.62 minutes to input the physician order and patient data, and print out the labels, mixing instructions, and decision
support clinical report. Although this difference approached significance \( (p = 0.108) \) the null hypothesis was retained at the 0.05 level. Actual computer label time, 5.142 minutes, indicated a significant mean difference of 2.438 minutes over manual label time. To say that no difference could be found between total computer task time and manual label time indicates the labor saved by the user in receiving completed mixing calculations and a clinical report automatically. The computer printed this additional information in only 1.5 minutes time after printing the labels.

There was no difference in label time manually or by computer between pharmacist and technicians. Years of experience was correlated with computer label time \( (r = 0.471) \) and computer total task time \( (r = 0.660) \). Years of experience was not correlated with these tasks when performed manually. One can only speculate that more experienced personnel have had more experience using computers. The manual label format and calculation worksheet were new forms and subjects received a short training session to adjust to these tasks. The newness and unfamiliarity of these forms may have superseded detecting manual differences due to subject education or correlation to years of experience. These are only speculations. The data and conditions of the test are insufficient to draw a cause and effect relationship.
Non-Distributive Utility Measures

The ability of pharmacy personnel to detect inappropriate orders based on having access to patient specific, diagnosis, associated medical problem parameters, age, weight, and current laboratory data, constitute a non-distributive pharmacy service goal, i.e. monitoring and facilitating rational drug therapy (Smith and Brown, 1982). The TPN program was specifically designed to provide users with a decision support patient specific clinical report. The purpose of the report was to assist users in detecting inappropriate order items. The report explained its reasoning process explicitly to the user to improve user confidence in using the report to make decisions about the appropriateness of the order items.

Certainly the training and experience received by registered pharmacists compared to technicians would be expected to result in superior skills in identifying order items for appropriateness. However, like the dilemma faced by many hospital pharmacies, none of the subjects had specialty training in neonatal hyperalimentation, yet all of these subjects were at times responsible for preparing these solutions.

Without computer aided decision support subjects performed poorly at detecting inappropriate orders (only 6.75 correct answers out of 12) and had very little
confidence in their determinations (65.328% on a scale of 50 to 100%). Pharmacists performed slightly better than technicians without the use of computer assisted aid (7.3 correct answers versus 6.2, p=0.03). However, their confidence was low (68.865%) and not significantly different than technicians (61.791%). Technician performance was not significantly better than guessing, i.e. (an expected outcome of 6 correct answers out of 12).

With computer assisted decision support all subjects performed significantly better with 11.65 correct answers (p <0.001), and with a higher degree of confidence (90.397%, p<0.001). Pharmacists scored slightly better than technicians in determining appropriateness but this difference was not significantly different at the 0.05 level (p=0.096). Pharmacists also scored higher in confidence, 93.416% versus 87.377%, but this difference was not significant at the 0.05 level (p=0.06).

Neonatal hyperalimentation is an esoteric field and subjects not having specialty training or ongoing involvement in the clinical aspects of neonatal medicine were not expected to confidently detect inappropriate orders proficiently. The relationship of pharmacy task performance in identifying order item appropriateness is related to the composite accuracy and confidence of the user. The least desirable performance is exemplified by the user who is repeatedly highly confident and highly inaccurate, while the
ideal composite performance would comprise the user who is consistently highly confident and accurate. One study objective thus sought to quantify the impact on user composite performance by level of experience of computer assisted determination of appropriateness versus manual determination of appropriateness.

The composite performance scale ranged from a possible score of -1200 to +1200. This scale integrates confidence and appropriateness. Subjects who are highly confident and wrong will score low, while subjects who are highly confident and correct will score high. This scoring system is therefore able to discriminate effects due to guessing.

Without computer assisted aide all subjects performed better than guessing (152) versus (0.0), (p=0.03). Pharmacists performed better than technicians (115.712 versus 31.5). This difference in manual performance between pharmacists and technicians was highly significant (p<.001).

With computer aided decision support all subjects performed significantly better (composite performance = 1035.7 versus 152, p<.001). Pharmacist’s composite performance was slightly better than technicians (1102.0 versus 969.5, p=0.046).
Attitudinal Questionnaire

Decision-support systems are often hampered by the amount of information required by the user to input. For example, if a general requires a combat strategy consultation in a nuclear war that can be over in minutes and the decision support program requires the user two hours to enter the input information, the program becomes useless.

The usefulness of the system also depends on the importance the user attaches to the consultation information. For example, not all pharmacists, or technicians, agree with the extent of pharmacy's responsibility to review order items for appropriateness. James Slagle and Michael Gaynor at the Navy Center for Applied Research in Artificial Intelligence, 1986, stated this problem in the following axiom, "User utility is inversely proportional to input time required of the user, and directly proportional to the user perceived importance of the output."

The TPN program developed for this project was designed to assist users in identifying order appropriateness based on entering a minimal amount of information, i.e., the order, current date, name of patient, date of birth, and patient weight. A much more sophisticated clinical report could be produced if users were willing to enter 12 to 35 additional input fields for patient parameters and lab values. Additional input fields
would provide a more sophisticated report but double the time of the input task.

One objective of this study was to quantify and compare pharmacist and technician perception of the importance of pharmacy's responsibility to review order items for appropriateness. In this study all subjects very strongly agreed that pharmacy has a responsibility for reviewing order items for appropriateness. It was suspected that technicians might not share the same attitude as pharmacists. There was no difference detected in pharmacist and technician attitude toward pharmacy's responsibility for reviewing order items for appropriateness. Pharmacists and technicians both agreed very strongly that this is an important pharmacy responsibility.

Additional input fields would require more user task time but give the user a more sophisticated clinical report. Another objective sought to quantify and compare pharmacist and technician willingness to enter additional input data to obtain a more sophisticated clinical report.

All subjects were willing to very willing to enter 12 to 35 additional input fields on a routine basis. There was no difference detected between pharmacist and technician willingness to enter additional data.

It was suspected that pharmacists might attach more importance to reviewing order items for appropriateness and
be more willing to enter additional data if a more useful clinical report could be achieved, than technicians. The comments from pharmacists and technicians after the test pointed out an unexpected finding. Input time to fill in the screen was very short and most users felt that inputting an additional 12 to 35 fields would not be very time consuming. Participants also commented that they felt it would be more time efficient for the program to review the lab and patient data automatically, rather than having the clinical report guide the user to manually review the lab data for specific purposes in decision making.

This study sought to quantify the relationship between the perceived importance of pharmacy's responsibility to review order items for appropriateness and willingness to enter additional input data. If Slagle and Gaynor's axiom is correct the users who attach a high importance to reviewing order items for appropriateness would also be more willing to enter additional input data. To better understand the utility of pharmacy based expert consultation systems for future planning the study sought to confirm the relationship between these constructs. According to Gaynor and Slagle's axiom willingness to enter was expected to be positively correlated with importance of reviewing. In this study all subjects were very willing to enter and very strongly agreed with the importance of reviewing. Therefore, the sample did not show a significant
correlation between these variables. One possible explanation is that the volunteers may have represented a group that is highly interested in computers and believe strongly in pharmacy's role in monitoring and facilitating rational drug therapy. There may be some halo effect at work. Whether this attitude universally pervades the pharmacy community is a matter of conjecture. Given a larger sample it may have been possible to detect a correlation between these variables.

**Alpha Slippage**

The major problem resulting from the performance of a series of analytic statistical procedures on a set of data is the unpleasant fact that the more comparative tests we conduct, the more type I errors we will make when the null hypothesis is true (Keppel, 1973). If 20 t-tests were performed at the 0.05 alpha level we can expect that we might falsely reject the null hypothesis for one of these tests. An approximation of the experiment-wise error would be (20 times 0.05). One solution to this problem is to employ a modified Bonferroni technique. That is, we could adopt a modified alpha level equal to the apriori alpha level divided by the of number tests employed to re-access our findings.
In Table 11., page 209 we conducted 6 dependent t-tests comparing computer versus manual outcome measures. If we modify the 0.05 alpha level to 0.05 divided by six tests our new alpha level would be 0.0083. Adopting an alpha level of 0.0083 would have little effect in influencing hypothesis testing for these measures. All of the results in this table demonstrate probabilities less than 0.001 for differences in outcome measures when using the computer compared to manual methods. The problem of alpha slippage does not change our conclusions. The use of the computer in this sample saved time, decreased mathematical errors, improved users performance in identifying inappropriate order items, confidence and composite performance.

Fourteen independent t-tests were performed comparing various utility measures between pharmacists and technicians, (See Table 12., page 210). Only one of these tests demonstrated a robust difference when corrected for alpha slippage. Pharmacist manual composite performance was higher than technician composite performance, (p<0.001). Using a modified alpha of 0.05 divided by 14, or 0.0036, none of the other differences between pharmacists and technicians previously cited as significant at the 0.05 level are robust enough to reject the null hypothesis at a 0.0036 modified alpha level.
Cost Analysis

An objective of the study was to identify the microcomputer program development cost. The evaluation identified the program development cost at approximately $9250 to $10,450. The program evaluation technique also demonstrated that distributive and non-distributive pharmacy task utility measures were favorably influenced by the computer program intervention.

This goal of this evaluation was exploratory. There were no pre-set outcome criteria levels. For example, it was not pre-determined that the program would be useful only if its cost was less than a certain dollar amount and the computer saved 10 minutes over the manual method or effected a 10% reduction in mathematical errors, etc.

The results of this study could justify adopting a custom developed microcomputer program merely based on the time savings. If a hospital pharmacy saved 16.948 minutes per bottle of TPN prepared, at $10.00 per hour technician time, this would effect a labor savings of $3.54 per bottle. The program would pay for itself after 2824 bottles. For even a small hospital preparing 4 to 8 bottles of neonatal hyperalimentation per day, the time labor savings would equal initial development cost in one to two years.

It is more difficult to quantify the benefits of decreased mathematical errors or identifying order item appropriateness and equating those benefits with program
development costs. A simple mathematical error can result in an extended hospital length of stay and additional laboratory tests due to iatrogenic metabolic imbalance. A serious mathematical error or failure to identify an inappropriate order could result in patient death. Koren's study has demonstrated that physicians, nurses and pharmacists are all capable of mathematical errors. The consequences of even a simple mathematical error could result in severe patient morbidity, mortality and malpractice litigation.

Data processing departments and administration have traditionally viewed custom designed departmental microcomputer programs as expensive extravagances, serving a limited number of users, further fragmenting data processing resources and a questionable allocation of funds. Given that there is some propensity for physicians and pharmacists to commit mathematical errors, an argument can be made that, pharmacy will likely at some time be faced with a potentially lethal order merely due to human error. In this study, pharmacy ability to detect questionable, potentially lethal orders was dramatically enhanced. An argument could be made for the adoption of this custom developed microcomputer program, based on intangible benefits.
Conclusions

1. Manual distributive task performance in the preparation of neonatal hyperalimentation, i.e. label generation and calculating mixing instructions, is time consuming, and prone to human mathematical error. These problems are equally shared by both pharmacists and technicians. No discernible differences in manual total task time, label time or number of mathematical errors, can be attributed to education and licensure or years of experience.

2. The computer program intervention dramatically improved label time, total task time, and decreased mathematical errors. Distributive performance outcome was equally improved for pharmacists and technicians.

3. Manual non-distributive task performance; i.e. identifying clinically inappropriate order items, confidence in making clinical decisions and composite performance are difficult esoteric tasks for non-specialty trained personnel. Manual confidence in making these determinations were low for both pharmacists and technicians. Pharmacists identify inappropriate order items better than technicians. Technician performance was not statistically different than that expected from guessing. Composite performance derived from correctly identifying inappropriate order items and confidence was higher for pharmacists.
3. Computer assisted decision support in determining appropriateness, confidence and composite performance was considerably superior to manual decision making for both pharmacists and technicians. Computer assisted composite performance, while both near perfect for pharmacists and technicians, was superior for pharmacists.

4. Pharmacists and technicians, strongly agree that pharmacy has a responsibility for reviewing order items for clinical appropriateness and are very willing to enter additional clinical input data to obtain a sophisticated computer assisted clinical decision support report.

5. The results of the alpha phase test indicate that the computer program intervention can dramatically improve distributive and non-distributive pharmacy task performance in preparing neonatal hyperalimentation at a cost of approximately $10,000.
Recommendations

A future study, as a result of this project would logically take place in a hospital. The program would be beta phase tested to evaluate its impact in the care of patients. Based on the information gained by this alpha test the program should be modified to allow laboratory data input and a more sophisticated algorithm written to supply a very detailed specific report.

There are several commercial programs currently available to pharmacists to assist with neonatal and adult hyperalimentation. These programs all claim to offer support and automation of distributive task functions. Some of these commercial programs also claim to assist users in clinical pharmacy activities. Future studies in the area of neonatal hyperalimentation are needed to compare existing commercial applications. A cost effective analysis model comparing costs and utility measures among the various alternatives is needed.
The Future

Based upon the experience gain from researching and developing this project the following projections are suggested by the author:

1. The current level of microcomputer technology hardware and software is capable of supporting useful decision-support systems to provide consultation systems for a specific professional purpose.

2. These development tools can be used to support traditional computer applications such as automated mixing instructions and label generation for neonatal hyperalimentation as well as provide the user with information to assist in identifying inappropriate orders.

3. This study would indicate that pharmacists and technicians performance for distributive and non-distributive tasks can be facilitated by computer assisted programs.

4. Computer applications can aid distributive pharmacy task goals by saving time and decreasing mathematical errors and simultaneously integrate useful decision support algorithms to aid users in monitoring and facilitating rational drug therapy.

Expert systems and decision support applications are emerging from the experimental laboratory and slowly finding
practical application in patient care. For these systems to be useful they will have to be designed such that they require a minimum of time and effort from the user. These systems will therefore need to be integrated or have electronic access to mainframe hospital information systems. A great deal of work and research will be needed to prove the benefit of these systems, to convince hospital administrators of their cost effective application and to convince vendors of their necessity and commercial viability.

Medical professionals are inescapably being caught up in controlling infospace, i.e., information system planning for automated control and efficiency. Computer applications will ultimately find practical application in low level mundane automation and integrate high level medical decision support applications. Pharmacy education like other professional fields will by necessity need to integrate computer science and management information systems studies into their curriculum. As medicine advances in the information age, more of the mundane work such as record keeping and counting pills will become automated. Technicians are evolving as technologists, and medical professionals are evolving as medical knowledge engineers. Pharmacy's ability to lead the way in research and development in the infospace process will determine our professional role as architect or worker bee.
Currently the "TPN" program is being used at the Naval Hospital Camp Pendleton to prepare pediatric and neonatal hyperalimentation orders. As previously stated clinical applications change frequently. The program has already been modified to use Trace Elements V. The program is being modified to accept laboratory data via a modem from a mainframe hospital laboratory mini-computer, automatically, and to incorporate this information into a more sophisticated clinical report.
APPENDIX A

STUDY FLYER: REQUESTING VOLUNTEERS
Will computer systems free personnel from tedious tasks? Would they make life in the pharmacy easier? Can they really save time, decrease errors and help us make better decisions about patient therapy?

If you are a registered pharmacist or a pharmacy technician with any amount of hospital intravenous additive experience you qualify to participate in the computer study.

The study only takes one hour of your time. It's easy. All results remain confidential. Subjects will be paid $10.00 for their participation.

If you think computer systems are important to the future of pharmacy, you are invited to try it out and tell us what you think!

CONTACT: DAN ANGELIER
626-5364 until 6pm
School of Pharmacy
Second floor
887-2933 evenings
Room # 20F
APPENDIX B

TRAINING PACKET
**NEONATAL HYPERALIMENTATION PATIENT DATA and ORDER**

(TRAINING SAMPLE)

**Date:** 9 June 1987  **Patient:** Brown, Babygirl Hospital ID:

**Ward:** NICU  **Date of Birth:** 1 June 1987

**Patient Diagnosis:** 28 weeks gestation, premature, with RDS

**Laboratory Values:** 9 June 1987  **weight:** 2.0 kg

**serum analysis:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>K</td>
<td>6.0 MMOL/L</td>
</tr>
<tr>
<td>Cl</td>
<td>100 MMOL/L</td>
</tr>
<tr>
<td>CO2</td>
<td>19</td>
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<tr>
<td>GLU</td>
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<tr>
<td>BUN</td>
<td>11 mg/dL</td>
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<tr>
<td>CR</td>
<td>.5 mg/dL</td>
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<tr>
<td>OSM:295 OSOMOL</td>
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</table>

**urine analysis:**

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<tbody>
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<tr>
<td>CA</td>
<td>8.7 MMOL/L</td>
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<td>Ca</td>
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<tr>
<td>PHOS</td>
<td>7.0 mg/dL</td>
</tr>
<tr>
<td>PH</td>
<td>7.0</td>
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<tr>
<td>ALB</td>
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<tr>
<td>TP</td>
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</tr>
<tr>
<td>CR</td>
<td>.5</td>
</tr>
<tr>
<td>HBG</td>
<td>15.1</td>
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<tr>
<td>HGT</td>
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<tr>
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<tr>
<td>BANDS</td>
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<tr>
<td>LYMPHS</td>
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<tr>
<td>MONOS</td>
<td>3%</td>
</tr>
<tr>
<td>EOSINOS</td>
<td>5%</td>
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<tr>
<td>BASOS</td>
<td>1%</td>
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</table>

**NEONATAL HYPERALIMENTATION ORDER**

(TRAINING SAMPLE)

1. To peripheral TPN line infuse the following TPN solution at 10 ml per hour (a 24 hour volume of 240 ml).

- **Dextrose:** 12.0%
- **Trace elements (PTE5):** 4.0 ml
- **Trophansine:** 6.0 g
- **HVI Pediatric:** 4.0 ml
- **Sodium Chloride:** 4.0 mEq
- **L-Cysteine:** 100.0 mg
- **Sodium Acetate:** 2.0 mEq
- **Iodine:** 10.0 mcg
- **Potassium Chloride:** 4.0 mEq
- **Potassium Phosphate:** 4.0 mEq
- **Magnesium Sulfate:** 1.0 mEq
- **GSAD Sterile Water:** 240 ml
- **Calcium Gluconate:** 4.0 mEq
- **Heparin:** 200.0 units

2. Also to the same line infuse fat emulsion 20% solution at 2.0 ml/hr over 24 hours.

**Dr. Prolog**  **9 JUNE 1987**
TPN Solution Calculations:

1. 24 hour Volume:
TPN Rate: \( \frac{200 - 50}{240} \) ml/hour = \( \frac{240}{24} \) ml/hour

2. Overfill Factor:
24 Hour Volume = \( \frac{240}{24} \) ml Final Volume

3. Grams Dextrose:
24 Hr Vol. x \( \frac{4}{10} \) Dextrose = \( \frac{100}{1} \) g Dextrose

4. MLS of TPN Additives and Sterile Water Calculations:
(Order Item) x (Overfill Factor) ÷ (Conc.) = (Volume of Additive)

5. Sterile Water to qs to Final Volume:
Final Volume = \( \frac{240}{24} \) ml + Additives + 50 ml Sterile Water

6. Calcium Phosphate Product:
NOTE Calcium phosphate product greater than 400 will precipitate!

7. Fat Emulsion:
Fat Rate ml/hour \( \frac{2.0}{24} \) x 24 Hours = 48 ml 24 Hour Fat Volume
Fat Rate ml/hour + 10 ml Overfill = \( \frac{58}{24} \) Minimum Volume

Circle the smallest standard 20% fat bottle that just exceeds the Minimum Volume calculated. => 50 ml 100 ml 250 ml 500 ml
APPENDIX C

TEST PACKET: ORDER A
PLEASE NOTE:

The following page contains poor print.

BEST COPY AVAILABLE, FILMED AS RECEIVED
NEONATAL HYPERALIMENTATION PATIENT DATA and ORDER A

Date: 9 June 1987  Patient: Smith, Babyboy Hospital ID—
Ward: NICU  Date of Birth: 1 June 1987
Patient Diagnosis: 29 weeks gestation, premature, with RDS
Laboratory Values: 9 June 1987 weight: 1.0 kg

Na: 138 MMOL/L  K: 6.0 MMOL/L
Cl: 100 MMOL/L  CO2: 19 MMOL/L
GLU: 70 mg/DL  BUN: 11 mg/DL
CRE: 5 mg/DL  OSM: 295 OSMOL/L

HGB: 15.1 g/dl  HCT: 51.1
WBC: 9.0 *1000  PLTS: 180K
RBC: 323 aoga  DIFFERENTIAL

LABORATORY VALUES:

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<td>BASOS</td>
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</tr>
<tr>
<td>OSM</td>
<td>295 OSMOL/L</td>
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NEONATAL HYPERALIMENTATION ORDER A

1. To peripheral TPN line infuse the following TPN solution at 1 ml per hour (a 24 hour volume of 216 ml):

- Dextrose 20.0%
- Trace elements (PTE5) 2.6 ml
- Trophamine 4.1 g
- NVI Pediatric 3.4 ml
- Sodium Chloride 1.6 mEq
- L-Cysteine 100.0 mg
- Sodium Acetate 1.2 mEq
- Iodine 5.0 mEq
- Potassium Chloride 3.6 mEq
- GSAD Sterile Water 24 hr vol.
- Potassium Phosphate 4.4 mEq
- of 216 ml
- Magnesium Sulfate 0.4 mEq
- Calcium Gluconate 1.9 mEq
- Magnesium 100.0 units
- Iodine 5.0 mEq

2. Also to the same line infuse fat emulsion 30% solution at 2.0 ml/hr over 24 hours.

Dr. Cadmus 9 JUNE 1987
REVIEWING ORDER ITEMS FOR APPROPRIATENESS

You are requested to check each of the following questions as appropriate or inappropriate. Inappropriate order items if present will be blatant overdoses, underdoses or contraindications. You do not have previous orders or a history of lab values. You must make your determination based on the patient's current age, weight, a brief diagnosis, and today's current lab values.

Your confidence in determining order item appropriateness will vary depending on your level of knowledge and experience. A complete guess would be rated 50%. If you are absolutely certain of your determination then your confidence can be rated as high as 100%. You are requested to rate your level of confidence from 50 to 100% in determining the appropriateness of order item.

For the following questions check whether you think the order item is appropriate or inappropriate. Then rate your confidence in this determination by writing a number from 50% to 100%.

1. The total daily fluid volume from fat and TPN is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

2. The protein delivered by the TPN solution for this patient is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

3. The osmolality of the TPN solution for this patient is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

4. The sodium delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

5. The total potassium delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

6. The total calcium delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

7. The magnesium delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

8. The potassium delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

9. The NRT pediatric delivered per 24 hours is apparently:
   - Appropriate: ______
   - Inappropriate: _____
   - Confidence: ______% (50-100)

10. The total phosphate delivered per 24 hours is apparently:
    - Appropriate: ______
    - Inappropriate: _____
    - Confidence: ______% (50-100)

11. The calcium phosphate product for this TPN solution is apparently:
    - Appropriate: ______
    - Inappropriate: _____
    - Confidence: ______% (50-100)

12. The amount of fat delivered per 24 hours is apparently:
    - Appropriate: ______
    - Inappropriate: _____
    - Confidence: ______% (50-100)
APPENDIX D

TEST PACKET: ORDER B
NEONATAL HYPERALIMENTATION PATIENT DATA and ORDER B

Date: 9 June 1987  Patient: Jones, Babygirl  Hospital ID_____
Ward: NICU  Date of Birth: 1 June 1987
Patient Diagnosis: 28 weeks gestation, premature, with RDS

Laboratory Values: 9 June 1987  weight: 1.0 kg

serum analysis:

Na: 138 MNOL/L  PLTS: 180K  Mg: 1.7 meq/L  Output: 60ml/24hr
K: 6.0 MNOL/L  WBC: 5.0 x1000  CA 8.7 MNOL/L  OSM: 400mosm/1
Cl: 100 MNOL/L  RBC: 323 megs  PHOS 7.0 mg/dl  PH: 6.0
CO2: 19 MNOL/L  HBG: 15.1  ALB 3.4 g/dl  Na: 40
GLU: 70 mg/DL  HGT: 51.1  TP 0.5 g/dl  K: 10
BUN: 11 mg/DL  DIFFERENTIAL  NH3 30 UMOL/L  SG: 1.014
CR: .15 mg/DL  SEG 55%  BILITOT 9 mg/dl
OSM: 295 OSMOL  BANDS 3%  SGOT 40 IU/L
LYMPH 34%  TRYGLY 170 mg/L
MONOS 4%  SGPT 20 IU/L
EOSINOS 5%
BASOS 1%

NEONATAL HYPERALIMENTATION ORDER B

1. To peripheral TPN line infuse the following TPN solution at 9
ml per hour (a 24 hour volume of 216 ml).

Dextrose  20.0%  Trace elements (PTE5) 2.6 ml
Trophanine 4.2 g  MVI Pediatric  3.4 ml
Sodium Chloride 1.9 meq  L-Cysteine 100.0 mg
Sodium Acetate 1.1 meq  Iodine 5.0 mcg
Potassium Chloride 3.4 meq
Potassium Phosphate 4.5 meq  QSAD Sterile Water 24 hr vol.
Magnesium Sulfate 0.5 meq  of 216 ml
Calcium Gluconate 1.8 meq
Heparin 108.0 units

2. Also to the same line infuse fat emulsion 20% solution at 2.5
ml/hr over 24 hours.

Dr. Mycin  9 JUNE 1987
REVIEWING ORDER ITEMS FOR APPROPRIATENESS

You are requested to check each of the following questions as appropriate or inappropriate. Inappropriate order items if present will be blatant overdoses, underdoses or contraindications. You do not have previous orders or a history of lab values. You must make your determination based on the patient's current age, weight, a brief diagnosis, and today's current lab values.

Your confidence in determining order item appropriateness will vary depending on your level of knowledge and experience. A complete guess would be rated 50%. If you are absolutely certain of your determination then your confidence can be rated as high as 100%. You are requested to rate your level of confidence from 50 to 100% in determining the appropriateness of order item.

For the following questions check whether you think the order item is appropriate or inappropriate. Then rate your confidence in this determination by writing a number from 50% to 100%.

1. The total daily fluid volume from fat and TPN is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

2. The protein delivered by the TPN solution for this patient is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

3. The osmolality of the TPN solution for this patient is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

4. The sodium delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

5. The total potassium delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

6. The total calcium delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

7. The magnesium delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

8. The heparin delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

9. The MVI pediatric delivered per 24 hours is apparently:
   Appropriate: _____ Inappropriate: _____
   Confidence: ______% (50-100)

10. The total phosphate delivered per 24 hours is apparently:
    Appropriate: _____ Inappropriate: _____
        Confidence: ______% (50-100)

11. The total calcium phosphate product for this TPN solution is apparently:
    Appropriate: _____ Inappropriate: _____
        Confidence: ______% (50-100)

12. The amount of fat delivered per 24 hours is apparently:
    Appropriate: _____ Inappropriate: _____
        Confidence: ______% (50-100)
APPENDIX E

MANUAL CALCULATION WORKSHEET
TPN Solution Calculations:

1. **24 hour Volume:**
   
   \[ \text{TPN Rate} \times 24 \text{ Hour} = 24 \text{ Hour Volume} \]

2. **Overfill Factor:**
   
   \[ \frac{\text{24 Hour Volume} + 50 \text{ ml}}{\text{24 Hour Volume}} = \text{Final Volume} \]

3. **Grams Dextrose:**
   
   \[ \frac{\text{24 Hr Vol.} \times \text{Dextrose} \times \text{factor}}{100} = \text{g Dextrose} \]

4. **Mls of TPN Additives and Sterile Water Calculations:**
   
   \[ \frac{\text{Order Item}}{\text{(Overfill Factor)}} \times \text{(Conc)} = \text{(Volume of Additive)} \]

   - Dextrose
     \[ \frac{\text{GM}}{\text{factor}} \times 0.7 = \text{ml} \]
   - Tropamine
     \[ \frac{\text{GM}}{\text{factor}} \times 0.06 = \text{ml} \]
   - Sodium Chloride
     \[ \frac{\text{mEq}}{\text{factor}} \times 2.5 = \text{ml} \]
   - Sodium Acetate
     \[ \frac{\text{mEq}}{\text{factor}} \times 2 = \text{ml} \]
   - Potassium Chloride
     \[ \frac{\text{mEq}}{\text{factor}} \times 2 = \text{ml} \]
   - Potassium Phosphate
     \[ \frac{\text{mEq}}{\text{factor}} \times 4.4 = \text{ml} \]
   - Magnesium Sulfate
     \[ \frac{\text{mEq}}{\text{factor}} \times 4.06 = \text{ml} \]
   - Calcium Gluconate
     \[ \frac{\text{mEq}}{\text{factor}} \times 0.47 = \text{ml} \]
   - Heparin
     \[ \frac{\text{units}}{\text{factor}} \times 1000 = \text{ml} \]
   - Phytonadione
     \[ \frac{\text{mcg}}{\text{factor}} \times 200 = \text{ml} \]
   - Trace Elements (PTE5)
     \[ \frac{\text{ml}}{\text{factor}} = \text{ml} \]
   - MVI Pediatric
     \[ \frac{\text{ml}}{\text{factor}} = \text{ml} \]
   - MVI Concentrate
     \[ \frac{\text{ml}}{\text{factor}} = \text{ml} \]
   - L-Cysteine
     \[ \frac{\text{mg}}{\text{factor}} \times 50 = \text{ml} \]
   - Folic Acid
     \[ \frac{\text{mcg}}{\text{factor}} \times 5000 = \text{ml} \]
   - Vitamin B12
     \[ \frac{\text{mcg}}{\text{factor}} \times 100 = \text{ml} \]
   - Regular Humulin
     \[ \frac{\text{units}}{\text{factor}} \times 100 = \text{ml} \]
   - Iodine
     \[ \frac{\text{mcg}}{\text{factor}} \times 2 = \text{ml} \]
   - Sodium Phosphate
     \[ \frac{\text{mEq}}{\text{factor}} \times 2 = \text{ml} \]

**SUM OF ADDITIVE VOLUME**

\[ + \text{ml} \]

5. **Sterile Water to qs to Final Volume:**
   
   Final Volume = Sum of Additives + \text{ml Sterile Water}

6. **Calcium Phosphate Product:**
   
   NOTE Calcium phosphate product greater than 400 will precipitate!

   \[ \text{NaPhosphate} \times 1.35 = \text{A} \]
   \[ \text{K Phosphate} \times 1.21 = \text{B} \]
   \[ \text{A} + \text{B} = \text{Total Phosphate} \]

   \[ \frac{1000}{\text{(____) 24 Hour Volume)}} = \text{____ M Factor} \]
   \[ \frac{(\text{Calcium (meq) (____) \times (M Factor (____)) = \text{A}} \]
   \[ \frac{(\text{Total Phosphate (meq) (____) \times (M Factor (____)) = \text{B}} \]
   \[ \text{A} \times \text{B} = \text{C} \]

   **NOTE:** \( \text{C} \) must be less than 400 or solution will precipitate!

7. **Fat Emulsion:**
   
   Fat Rate ml/Hour \times 24 Hours = 24 Hour Fat Volume
   \[ \frac{\text{24 Hour Fat Vol.} + 10 \text{ ml Overfill = Minimum Volume}}{\text{Minimum Volume}} \]

Circle the smallest standard 20% fat bottle that just exceeds the Minimum Volume calculated. \( \Rightarrow \) 50ml 100ml 250ml 500ml
APPENDIX F

REVIEWING ORDER ITEMS FOR APPROPRIATENESS
REVIEWING ORDER ITEMS FOR APPROPRIATENESS

You are requested to check each of the following questions as appropriate or inappropriate. Inappropriate order items if present will be blatant overdoses, underdoses or contraindications. You do not have previous orders or a history of lab values. You must make your determination based on the patient’s current age, weight, a brief diagnosis, and today’s current lab values.

Your confidence in determining order items appropriateness will vary depending on your level of knowledge and experience. A complete guess would be rated 50%. If you are absolutely certain of your determination then your confidence can be rated as high as 100%. You are requested to rate your level of confidence from 50 to 100% in determining the appropriateness of order items.

For the following questions check whether you think the order item is appropriate or inappropriate. Then rate your confidence in this determination by writing in a number from 50% to 100%.

1. The total daily fluid volume from fat and TPN is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

2. The protein delivered by the TPN solution for this patient is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

3. The osmolality of the TPN solution for this patient is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

4. The sodium delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

5. The total potassium delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

6. The total calcium delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

7. The magnesium delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

8. The heparin delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

9. The MVI pediatric delivered per 24 hours is apparently:
   - Appropriate: _______ Inappropriate: _______
   - Confidence: _______% (50-100)

10. The total phosphate delivered per 24 hours is apparently:
    - Appropriate: _______ Inappropriate: _______
    - Confidence: _______% (50-100)

11. The calcium phosphate product for this TPN solution is apparently:
    - Appropriate: _______ Inappropriate: _______
    - Confidence: _______% (50-100)

12. The amount of fat delivered per 24 hours is apparently:
    - Appropriate: _______ Inappropriate: _______
    - Confidence: _______% (50-100)
APPENDIX G

PRE-FORMATTED: LABELS
### TPN: Hospital Pharmacy I.V. Additive Dept.

**Hospital ID#:** 12102  
**Bag#:** __________

**Name:** Brown, Baogirl

**Date:** 6-9-1993  
**Start time:**  
**Rate:** __________ ml/hr

**Vol 24 hr:** 240 ml  
**overfill:** __________ ml

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<th>QT.</th>
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<td>ml</td>
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<td>mcg</td>
<td>Iodine</td>
<td>10.0 mcg</td>
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</table>

---

### TPN: Hospital Pharmacy I.V. Additive Dept.

**Hospital ID#:** 12101  
**Bag#:** __________

**Name:** Brown, Baogirl

**Date:** 6-9-1993  
**Start time:**  
**Rate:** 2.0 ml/hr

**Vol 24 hr:** 48.0 ml  
**overfill:** 52.0 ml

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<th>UNIT ITEM</th>
<th>QT.</th>
<th>UNIT</th>
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<tr>
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<td>meq</td>
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<td>mcg</td>
<td>Iodine</td>
<td>mcg</td>
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APPENDIX H

ATTITUDINAL QUESTIONNAIRE
REVIEWING ORDER ITEMS FOR APPROPRIATENESS

AND

WILLINGNESS TO ENTER ADDITIONAL LABORATORY DATA

Please respond to the following statements, by circling your response.

- Pharmacy has an important responsibility to review order items for clinical appropriateness.

very strongly strongly very strongly very
strongly agree agree neutral disagree disagrees strongly disagree
7-------6-------5-------4-------3-------2-------1

- A much more sophisticated and clinically useful report to aid in identifying clinical appropriateness could be produced if the user would be willing to input 12 to 35 additional fields of lab data and patient parameters. How willing would you be to routinely enter 12 to 35 additional data fields?

very strongly strongly very strongly very
strongly willing willing neutral notwill. notwill. strongly notwill.
7-------6-------5-------4-------3-------2-------1
APPENDIX I

COST ANALYSIS: MULTISOURCE INC. REPORT
The TPN Program - An Analysis and Evaluation
by Multi-source Corporation

July 16, 1987

I. Introduction

Multi-Source was engaged by Mr. Dan Angelier, a graduate student in the University of Arizona's Pharmacy Practice college, to evaluate the TPN program from a software engineering point of view. This evaluation was undertaken by Mr. James Boardman who is VP of Technology for Multi-Source.

Mr. Boardman's expertise is in the design and development of small to medium software projects specializing in the area of micro and mini computers with an emphasis on communication networks. Mr. Boardman has no practical experience with TPN or any other aspect of pharmacy practice.

II. Overview of the TPN Program - Software Viewpoint

From a software viewpoint, the TPN program falls within a class of programs that are typified by screen displays which ask the user to fill in data. Results are then computed after appropriate blanks are filled in by the user. This particular program displays a fair degree of sophistication and intelligence in its responses to the data being filled in. Default responses are used where appropriate and, in some cases, subsequent request fields are adjusted according to previously input data.

After forms have been filled out, various reports are available. The reports output by the TPN program are of average complexity (in terms of programming the formats for them) and also of average readability and "attractiveness".

III. Sophistication

As mentioned above, the TPN program is a fairly typical form-fill program and report generator. To reach the degree of sophistication exhibited by the TPN program, a substantial effort would be required to design the screen forms and to implement the logic that makes certain form-fill decisions. As a result, the degree of sophistication is estimated to be substantially above average for this type of program.

IV. User-Friendliness

The TPN program exhibits a good degree of user-friendliness. Help is available on-screen and this alone puts the program at least one cut above many programs available for PC computers. The help conventions, however, are somewhat foreign to an average user of PC systems who make use of packages such as 1-2-3 or dBase. These differences, however, are not very significant because every software program has its own set of conventions that a user must become accustomed to.
V. Cost

This evaluator did not participate in either the design or the coding of the TPN program. However, after a short demonstration of its capabilities and after examining the software modules this evaluator has reached the conclusion that approximately 50 hours of design time would have been required. Design time is time spent by a systems analyst interacting with a client who is requesting the development of a package. The result of design time is set of specifications from which a programmer may begin the coding process. A systems analyst fee for 50 hours of design time would be approximately $2500.

The programming effort to develop the TPN program would depend heavily on the degree to which previously developed libraries of routines are available. Often, a programmer has previously developed many common routines such as date/time manipulation software routines, screen painting, user interaction and report generation routines.

The evaluation here assumes that no program library routines were available. An "average" programmer can produce between 10 and 20 lines of code per hour in a high level language such as Fortran or Pascal. The TPN program is completely written in Pascal and is comprised of about 3000 lines of code. Based on these numbers, the programming time required would be between 150 and 300 hours. Taking an average of 225 hours and an average programmer's fee of $30 per hour, the programming cost to develop this program would have been about $6,750.

VI. Summary

The TPN program is a fairly typical fill-in-the-blanks and write-a-report program. It exhibits above average degrees of sophistication, complexity and intelligence. It has average user-friendliness.

The total cost for developing TPN to a Beta-test stage is estimated at $9,250. Further work is typically required by the designers and programmers to bring a software package to production level. It is not clear that TPN has really reached the production level and thus may require additional testing, evaluation and design and coding adjustments. It is not unusual for such adjustments and refinements to add an additional 30% to 50% on to the time and cost factors.

Multi-Source Corporation
7660 East Broadway
Suite #105
Tucson, AZ 85710
602-290-1717
July 16, 1987

Invoice No. 0713

To: Mr. Dan Angelier
College of Pharmacy
University of Arizona
Tucson, Arizona

Program evaluation and report - 1 hour @ $50/hr

$50.00

TOTAL DUE

$50.00

Terms: Net 10
APPENDIX J

RAW DATA AND DESCRIPTIVE STATISTICS
### Appendix J

**RAW DATA COLLECTION TABLE AND DESCRIPTIVE STATISTICS**

<table>
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<th>Subject (Ind. Var.)</th>
<th>(Dependent Variables)</th>
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**MEAN**
- 2.48 6.52 22.59 5.14 7.88 6.98 1.58 11.68 6.78 90.40 63.33 6.65 6.60 1085.75 152.00

**STANDARD DEVIATION**
- 1.58 1.06 4.06 1.09 2.18 0.00 0.60 0.67 1.61 7.24 9.64 0.49 0.72 420.63 168.07

**VARIABLE KEY:**
- (Independent Measures)
  - ORD: Order assigned for manual task (1=Computer, 2=Manual)
  - USR: User (1=Physician, 2=Technician)
  - YRS: Years i.v. additive experience
- (Dependent Repeated Measures)
  - TIMET(1-2): Total Task Time
  - TIMETL(1-2): Label Time
  - ERROR(1-2): Error Rate
  - APPRO(1-2): Appropriateness
  - CONF(1-2): Confidence
  - IMPREV: Importance of Reviewing
  - WILENT: Willingness to Enter
APPENDIX K

PEARSON CORRELATION MATRIX
Appendix K  

PEARSON CORRELATION MATRIX

TWO TAILED TEST AT THE 0.05 LEVEL
NUMBER OF OBSERVATIONS: 20
DEGREES OF FREEDOM: 18
SIGNIFICANT r IS > OR = 0.444

VARIABLE KEY:
{Independent Measures }
ORD - physician Order assigned for manual
task (opposite by cpu): A=1, B=2
USR - User: Pharmacist=1, Technician=2
YR - Years i.v. additive experience

{ Dependent Repeated Measures 1=Computer, 2=Manual }
TT(1-2) - Total Task Time
TL(1-2) - Label Time
ER(1-2) - Mathematical Errors
AP - Appropriateness
CF(1-2) - Confidence
I - Importance of Reviewing
W - Willingness to Enter
CP(1-2) - Composite Performance

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** NOTE:
Significant correlations are underlined.
**Appendix K (continued) PEARSON CORRELATION MATRIX**

**TWO TAILED TEST AT THE 0.05 LEVEL**

NUMBER OF OBSERVATIONS: 20

DEGREES OF FREEDOM: 18

SIGNIFICANT $r$ IS > OR = 0.444

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**** NOTE:
Significant correlations are underlined.
Correlation between willingness to enter additional input data and importance of reviewing orders for appropriateness was not significant, at the 0.05 level. (Hypothesis 14)**
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Trudeau T. The computer: current concepts and applications. topics in hospital pharmacy management. 1984; 1; 4: 29-36.

