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A SURVEY OF PSYCHOPHYSIOLOGICAL INSTRUMENTATION
AND OF ITS APPLICATIONS
IN EDUCATION, EDUCATIONAL PSYCHOLOGY AND COMMUNICATION

presented by

Richard Burtschi

has been accepted towards fulfillment
of the requirements for

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Allan J. Abedor
Major professor

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A SURVEY OF PSYCHOPHYSIOLOGICAL INSTRUMENTATION
AND OF ITS APPLICATIONS
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By

Richard Burtschi

A DISSERTATION

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ABSTRACT

A SURVEY OF PSYCHOPHYSIOLOGICAL INSTRUMENTATION AND OF ITS APPLICATIONS IN EDUCATION, EDUCATIONAL PSYCHOLOGY AND COMMUNICATION

By

Richard Burtschi

This study addresses the question of the diffusion of existing innovative, electronic and non-electronic instrumentation in areas where it is under-used or not used at all. The study develops, first, a picture of the types of instrumentation that are available. Then it focuses upon useage being made of five specific types of physiological instrumentation. Applications are then suggested for those five types in areas where they are under-used or not used at all. Finally, the results of the study are summarized and discussion is included of an organizational structure which might help bridge the gap between teachers or researchers and the technology discussed in the study. The goal of the study is, therefore, to attempt to identify and then recommend to teachers and researchers tools to which they may, previously, have had no introduction or access, and to propose means through which they might get that introduction and access.

To accomplish the above goal seven objectives were planned and accomplished for the study.

1) A taxonomy of available electronic and non-electronic instrumentation was developed.
2) A taxonomy of instrumentation applications and research problems which are addressed by the above instrumentation was developed.

3) A multi-disciplinary literature survey was done to determine who, in general, uses the types of instrumentation shown in the instrumentation taxonomy, and to determine how the instrumentation is used. This survey focused upon the first five categories of the instrumentation taxonomy, i.e. five forms of physiological instrumentation: brain waves (theta, alpha, and beta), muscle voltage measurement (EMG), skin conductance measurement (GSR), biofeedback and telemetry.
4) A narrower literature survey was done to determine within the fields of education, educational psychology and communication what uses are being made of the above five types of instrumentation.
5) A Coding Matrix was developed: a) to help categorize types of instrumented research, b) to identify and display areas for which the surveys did not find citations (suggesting, in some cases, what may be new areas of instrumentation application), c) to code the bibliography to facilitate location of citations dealing with a specified type of instrumentation application.
6) Interviews were held with researchers in education, communication and educational psychology to see if additional instrumentation applications could be added to those identified in the surveys conducted for objectives three and four.
7) An 'instrumentation resource center' structure was described and discussed. This structure could mediate technology to 'non-technical' persons.

Conclusions. The first conclusion is that there are, indeed, useful applications in the social sciences of the five types of instrumentation focused upon by this study. A variety of applications were identified for the fields of education, educational psychology and communication. It appears that a number of those applications have, to date, hardly been explored.

A second conclusion arises from interviews held with a variety of researchers and department heads at Michigan State University while this study was being done. These persons are aware of the potential usefulness of instrumentation in their areas and, without exception, expressed the desire to gain access to it. The conclusion arising from this is that it would be desireable to provide such persons access to instrumentation. Interest was expressed by persons in education, communication, physical education and recreation, music, osteopathic and human medicine, athletics (e.g. track and tennis), dietetics and speech and hearing. A number of teachers, e.g. of relaxation classes, communication, business and psychology classes indicated interest. Interest was expressed by clinical psychologists in private practice and connected with a pain clinic at a medical center. The diversity of persons expressing interest parallels the findings of the study as to where the most useful applications are being made, or are beginning to be made.

Recommendations. First, it is recommended that surveys such as those done for this study be done for other areas of the social sciences to identify instrumentation applications in those areas. Second, it is recommended that the taxonomies of instrumentation and research problems be further developed. Improvement of those taxonomies would make possible, for example, construction of a more thorough matrix for a field such as communication or education, identifying existing research and displaying areas where new activity might be initiated. Third, it is recommended that steps be taken to implement some form of 'instrumentation resource center' activity to mediate technology to teachers and researchers who wish to undertake use of new technology but who need assistance in acquiring and using it.

It is believed, based on the results of this study, that the areas of social science surveyed comprise a ready and fertile ground for efforts to diffuse innovations in instrumentation.

DEDICATION

This thesis is dedicated to my parents

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation tu the many persons who have helped in the various stages of development of this study.

Particular thanks are expressed to Dr. Allan Abedor for his excellent counsel while chairman of the guidance committee and during earlier phases of the doctoral program. Thanks are expressed to the other members of the guidance committee for their unique insights and their generous assistance. Drs. Abedor, Norman Bell, Richard Farace and James Nord each brought unique and invaluable perspectives on the subject of technological innnovation.

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This thesis was assembled and typed by Mrs. Pat Sweet. A more competent person technically, or one more gifted in good humor and interpersonal skills, would be difficult, indeed, to find.

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Chapter I

BACKGROUND

Within the last two decades a technological revolution has occurred which has touched virtually every area of our lives. There have been substantial improvements, as well as entirely new developments, in measurement instrumentation and the research procedures used with it. Norton (1969) writes:

> The rapid growth of the instrumentation field during the past decade has few parallels in history. The sophisticated electronic measurement systems now in routine operation in many countries would have appeared of marginal credibility as recently as the mid-1950's.

These developments have supplemented or transformed research activities in some areas of study, but not all. Some of the researchers who might have applications for such instrumentation, e.g. in the fields of education, communications, etc., are still experiencing the frustration of the technological communication barrier which must be crossed before they can reliably use such instrumentation. In this connection Wolff (1970) emphasizes the need for researchers to be aware of instrumentation:

> Most...people will simply not pose problems unless they are at least marginally aware of the technology which might be capable of producing a solution. What is needed, therefore, is someone who can say: "This or that new engineering technique is now available: My preliminary thinking and experimentation suggest that it ought to be useful to solve this or that...problem."

Beyond the fact that people need to know of instrumentation before being able to raise certain types of questions, there is another important fact related to its use. In some research situations, as in psychophysiological measurements, instruments can detect, record and process data in ways that the unaided human researcher cannot. For example, the human observer tends to forget and to distort data:

> So much of our raw data consists of brief impressions of evanescent, fleeting moments of behavior. They are here and gone in a flash, never to recur, never to be re-enacted or re-lived in exactly the same way.... It is this fleeting moment which must be studied. For this purpose it would have to be perceived, recorded and recalled with precision. Yet, we know that during the whole experience the observer himself is emotionally involved..... Yet, when we are involved emotionally, we are hardly free to make precise, objective, observations, to record them accurately, or to recall them without bias..... Parents and teachers and psychiatrists have all been dependent for their basic data upon their imperfect and fallible memories of visual and auditory perceptions which are themselves subject to distortion (Kubie, 1964).

Lawrence (1967) writes of the need for this type of study from the perspective of one in the Audio Visual field:

> Unfortunately, as it stands, the increased AV-type research activities supported in the past several years both by major educational foundations and by the Federal Government, especially under the provisions of Title VII of the National Defense Education Act, include no elaborate studies on the instrumentation philosophy and application of the bio-physical type systems to audiovisual use. Instead, due to a lack of something better, responsible personnel continue to wring out the semi-fixed possibilities of antiquated machines and Gestalt-type psychological concepts.

Need For The Study

It is important that researchers in the social sciences know of new, or improved, instrumentation. The primary reason for this is that new, or improved, instrumentation should yield new, or more refined, data. This, in turn, should enable researchers to get better answers to their research questions and, perhaps, to ask some new or better questions.

To provide researchers with an overview of available instrumentation it is necessary that they have access to some sort of inventory, or survey, of instrumentation useage. Such a survey should indicate possible applications, the types of data which can be acquired, and give an indication of the types of interpretation which can be placed upon that data. This survey should give researchers a better perspective as to what expectations might be placed upon such equipment. They should know both the strengths and limitations of their instrumentation. Finally, that survey can serve as a point of departure for efforts to identify research areas in which instrumentation, of the types reviewed, is used very little, or not at all.

Another critical need is to communicate to developers of instrumentation technology some of the unique needs of various areas of research, such as education, educational psychology and communications.

Finally, it is important that innovative research instrumentation be made available to researchers who might benefit from it. With a given instrument a researcher in communications or education is likely to generate different questions from what an experimental psychologist would generate. A study is needed, therefore, to promote the broader use of available technology, i.e., the diffusion of innovations in instrumentation. Rogers (1971) states:

> An innovation (italics) is an idea, practice, or object perceived as new by an individual. It matters little, so far as human behavior is concerned, whether or not an idea is "objectively" new as measured by the lapse of time since its first use or discovery. It is the perceived or subjective newness of the idea for the individual that determines his reaction to it. If the idea seems new to the individual, it is an innovation.

A study is, thus, needed which addresses the question of diffusion of instrumentation innovations.

The Generalizability of This Study

A survey of research instrumentation in education, educational psychology, and communications will be of interest to a variety of researchers outside those areas, whether in the social sciences, engineering, etc.. The research problems in any given area will dictate what forms of instrumentation are of value there.

The Objectives and Methodology of This Study

Seven objectives have been set for this study which are described in this section along with the methods employed to achieve them. In general, this study develops, first, a broad picture of the types of research instrumentation that are available (Chapter 2, Objectives 1 and 2). It then focuses upon useage being made of several types of psychophysiological instrumentation (Chapter 3, Objective 3: Chapter 4, Objectives 4 and 5). Applications are then suggested for those psychophysiological tools in areas where they appear to be little used (Chapter 4, Objective 6). Finally, the results of the study will be summarized and some discussion included of an organizational structure which might bridge the gap between researchers and the technology discussed in the study (Chapter 5, Objective 7).

The primary goal of the study is, therefore, to attempt to innovate through identifying and, then, recommending to researchers tools to which they may, previously, have had no introduction or access (Chapter 5, Objective 7, deals with means through which researchers might get that introduction or access).

Objective 1. The first objective of this study was to develop a taxonomy of research instrumentation and techniques. This taxonomy provides a listing and categorization of available instrumentation and serves as a background for chapters to follow. The instrumentation ranges from non-physiological to physiological and, within each category, from simple to more complex.

The procedure used to develop the taxonomy included the following: a) discussion of the rationale for an instrumentation taxonomy, b) searching through psychological, educational, medical, technical and other sources in an effort to locate instrumentation types, c) planning and justifying of the arrangement and 'ordering' of instrumentation within the taxonomy.

Objective 2. The second objective of this study was to develop a taxonomy of research problems which are addressed by the previously identified instrumentation. This taxonomy lists and categorizes a wide variety of research problems. For example, a variety of research problems can be identified under the heading of motor performance: fatigue, skill in manual performance, muscle tension, and hand-eye coordination. The research problem taxonomy will be used in juxtaposition with the instrumentation taxonomy to show applications of instrumentation.

The method used to develop the research factor taxonomy includes the following: a) discussion of the rationale for a research problem taxonomy, b) searching through psychological, educational, medical, technical and other sources in an effort to identify a variety of categories of research factors, c) arranging of the research problems according to the rationale developed.

Objective 3. The third objective of this study is to determine who, in general, uses the types of advanced instrumentation to be described, how it is used, and with what results. The method used to get this data was a multi-disciplinary survey of literature, including both manual and computer searches. The sources manually searched and the seven computer searches initiated were: a) any considered likely to contain citations about use of instrumentation and, b) those related to social science areas to be focused upon in Chapter 4. To facilitate follow-up study, details of the computer searches are given in Appendix A. Other information sources were used also, e.g., Dissertation Abstracts and various indexes to periodical literature.

The outcome sought from the above searches was citations describing research using the types of instrumentation focused upon by this study. The questions asked of the citations for objective number 3 were: Who uses advanced instrumentation, how, and with what results? A citation will be considered to be 'of value' to this study if it provides answers to one or all of those questions.

Objective 4. The fourth objective of this study was to determine within three selected subject matter areas who uses advanced instrumentation, how they use it, and with what result. The selected areas were education, communication and educational psychology. Education and communication were selected because they are areas in which little advanced instrumentation, if any, is being used, and because there are numerous potential applications there. Educational psychology was selected because it is an area in which some use of such instrumentation has been made but where there are further potential applications.

The method used to collect the needed data was a selective literature review of five research oriented journals within each of the chosen areas. Selection of those journals was based upon the recommendations of Michigan State University faculty within each of the areas and upon the results of the computer and manual searches in identifying potential sources.

The outcome sought from this intra-disciplinary survey was citations describing research using types of instrumentation focused upon by this study. This survey sought to determine: a) who, if anyone, within the areas searched has used advanced instrumentation, b) how they have used it and, c) what results they have reported.

Objective 5. The fifth objective of this study was to develop a coding system, in a matrix format, which will aid in identification of instrumentation applications and in selection of appropriate instrumentation for one's own research. Specific applications of the coding matrix in this study are: a) identification (coding) of types of instrumented research located in the computer and manual searches done for this study, b) identification and display of areas for which available research was not found in the surveys (empty cells in the matrix will, therefore, suggest either that research has not been done in a particular category or that it simply was not found in the surveys done for this study), c) coding the bibliography of this study to aid in the location of information involving the use of a particular type of instrumentation with a specified type of research problem.

The method used to develop the coding system matrix included the following steps: a) establishing a rationale for the coding system, b) selection of a matrix format, c) construction of the matrix.

Objective 6. The sixth objective of this study was to identify research applications in the three subject matter areas surveyed. Having determined by reviewing journals what is being done in those areas, and using the results of the broader search done for Objective 3, interviews were held with one experienced researcher in each of the three areas. This was, in effect, a 'consultant-consultant' interview in which the knowledge of interviewer and interviewee were pooled. The researchers interviewed were familiarized with the types of instrumentation being focused upon and with the results of the literature surveys conducted for purposes 3 and 4. After the above private interviews the three participated in a group discussion conducted with the intention of identifying new instrument applications.

The data being sought from the interviews and the discussion, therefore, was the judgment of subject matter experts and of the interviewer concerning new instrument applications in the fields of communication, education and educational psychology.

Objective 7. The seventh objective of this study was to present the theoretical and functional structure of an 'instrumentation resource center', the purpose of which would be to provide the organizational structure needed to disseminate instrumentation and technical assistance to researchers. As in the preceding objectives, the method used was to develop a rationale then to discuss an organizational structure. Based upon that structure it will be possible to draft a proposal for the testing of that structure at a major university. The drafting of the proposal itself is not, however, a part of this study.

Limitations Of This Study

This study does not deal with all electronic instrumentation, or non-electronic instrumentation, that is available. It focuses upon a few types which appear, on the basis of relative inexpensiveness and ready availability, to be transferable to use by social scientists and other 'non-laboratory' type researchers. It is not suggested that those types of instrumentation will be applicable to, or will improve the quality of data gotten in, all types of research or measurement. The instruments to be focused upon by this study are: 1) alpha wave and theta wave monitoring instruments, 2) skin conductance monitoring instruments (galvanic skin response), 3) muscle voltage monitoring instruments (electromyographic measurement), 4) physiological feedback techniques (provision of feedback to the person from whom measures are being taken), 5) physiological telemetry techniques.

This study will not deal with legal considerations important in instrumentation use. There are, for example, laws relative to researchers and persons who serve as research subjects. These are concerned with the types of research done, the procedures used, the competency of the researcher. Also, laws are being drafted concerning the types of instruments that will be considered safe for human research. For example, the United States Congress is currently preparing for passage of the Medical Device Amendments of 1976 (see Federal Register, Vol. 14, No. 173, Friday, September 3, 1976) which is concerned with the safety of devices and with the determination of the real therapeutic value of devices to be used for medical purposes.

Definition of Terms

Because some readers of this study will be unfamiliar with some of the terminology of the study this section will include elaborated definitions. Several definitions are accompanied by references to the taxonomy of instrumentation in Chapter 2. Reference to that taxonomy will facilitate understanding of the definitions given.

Bioelectric potentials. These are voltages generated by electrochemical activity in certain types of cells in the body. Such identifiable voltages are produced by systems in the body as they carry out their functions. They provide a good deal of information on various aspects of system function. For example, bioelectric potentials are found in connection with such activities as heartbeat, brain activity, muscle activity and nerve conduction.

Alpha waves. Electroencephalography is the term used to describe the process of detecting voltages on the surface of the head. Alpha waves are one type of bioelectric voltage measured there which will be discussed in this study. Alpha waves appear as a series of waves occurring at the rate of approximately 8 to 12 waves per second. The frequency ranges of voltages appearing on the head have been arbitrarily assigned Greek letter names (Delta, voltages below 4 waves per second; Theta, voltages at 4 to 8 waves per second; Alpha, voltages at 8 to 13 waves per second; Beta, voltages above 13 waves per second). The functions within the brain producing these waves are not fully understood. However, they appear to be related to responses to sensory stimuli, visual activity, relaxation, anxiety, attention and fatigue. Subjects seem to be able to exercise a remarkable degree of voluntary (indirect) control over the rate and amplitude at which these waves are produced and, consequently, over the factors listed above.

Electromyography. This is the technique by which bioelectric voltages developed within muscles are measured. These voltages are proportional to muscle activity or tension. They can be measured at the surface of the skin above the muscles of interest or through use of needles which penetrate the skin. Research has shown that subjects can exercise voluntary, but indirect, control over the level of activity in some muscles. They can, for example, condition themselves to 'relax' muscles and, thus, perform motor functions more efficiently.

Feedback and classical conditioning. These two terms are listed together not because they mean the same thing but, rather, because they have a common function. The autonomic nervous system cannot be directly and voluntarily controlled but conditioning and feedback are two techniques through which that system can be influenced indirectly. In Pavlovian conditioning a stimulus which, initially, is neutral, such as a sound, can be caused to get the same response from an animal as a natural stimulus, such as the sight of food, if the neutral stimulus is presented to the animal several times just prior to the natural stimulus. This is Pavlovian 'classical' conditioning.

Biological feedback is another means of indirectly influencing the autonomic nervous system. If an autonomically controlled activity is monitored by an instrument and a subject sees, hears or feels immediately when a change in that function has occurred then the individual can, in some cases, learn to influence the function. For example, if a subject hears the sound of the heartbeat research indicates that some, but not all, persons can learn to influence the rate of the beat upward or downward. Such influence has been claimed over skin temperature, alpha waves (and other brain waves), heart rate, skin conductance, muscle activity, blood flow in certain parts of the body, insulin production, urine production and stomach acidity.

Galvanic skin response (GSR). This is the measurement of electrical resistance of the skin and tissue path between two points on the surface of the skin. The resistance might vary from 1000 to greater than 500,000 ohms. These variations are influenced by the activity of the autonomic nervous system. Changes in emotional state, various reactions, such as fear or anger, cause measurable changes. These changes can be made observable as meter needle movements, changes in pitch of a sound, changes in lights, or in recordings on a chart recorder. This instrument is one used in 'lie detector' systems. Use of feedback of skin conductance is made to enable subjects to indirectly control the conductance. In controlling conductance one exercises indirect control over states that cause the changes. For example, some subjects can learn to reduce the amount of conduction change occurring when confronted with various types of stressful stimuli. In other words, the person is learning to 'relax', to show less of this particular response to those stimuli.

Instrumentation. This term describes 'tools' used in the acquisition of research data. In this study the term includes research techniques, software and hardware. For example:

1. Non-hardware data gathering tools: e.g. questionnaires, self-report formats, discussion formats, simulation and games, designed for the purpose of generating research data. In the taxonomy of instrumentation, Chapter 2, see categories 17 and 18.
2. Procedures, software and hardware used for observation (monitoring) of characteristics of research subjects through visual, aural, tactile, and other means, using instruments to aid in observation and/or storing, processing and displaying of data (e.g., cameras, audio telemetry, recorders, computers, etc.). These types of instrumentation are shown in the taxonomy of instrumentation, Chapter 2, categories 9 to 16 and 19 to 21.
3. Physiological measuring and monitoring instruments which measure, record, process and/or display data relative to physiological and emotional activities of research subjects. See the taxonomy of instrumentation categories 1 to 8. As stated earlier, this study will focus its attention on categories 1 to 5.

In the course of this study the terms 'advanced instrumentation' are used frequently to describe the physiological instruments in categories 1 to 5. The word 'advanced' implies that they require special background information and a knowledge of techniques which most researchers, social scientists, etc., will not initially have. This study discusses, in Chapter 5, ways in which that information can be gotten by them.

Psychophysiological measurements. Some cognitive or affective activities are reflected in measurable physical effects, e.g., a change in a voltage or some other change at some location in the body. A psychophysiological measurement is one made of that physical effect with the purpose of interpreting the effect in terms of the mental activity.

Researcher. This term is used to describe the target audience of this study. It is meant to include researchers in the fields of education, communication, educational psychology, music and physical education, or any other area which can benefit from instrumentation use.

Telemetry. This word means 'to measure at a distance.' Any sound, pressure, acceleration, temperature or physiological measure can be transmitted to a distant monitoring point, whether inches or miles away. The transmission can be by radio wave, wires, light, sound or infra-red. When the measurement is of a physiological or biological activity the term used to describe it is 'biotelemetry.' One of the principal advantages of telemetry is that it can free subjects from wires and lab restraints so that research is less obtrusive upon the natural activity and behavior of the subject.

Overview Of The Chapters To Follow

Since the first intention of this study is to develop a picture of types of research instrumentation and techniques that are available Chapter 2 will take the first steps in that direction. It will contain taxonomies of research problems, and of instrumentation and techniques.

Chapters 3 and 4 of this study will present the findings of two literature surveys. The first survey was a broad one intended to locate as many sources of information as possible on the types of instrumentation of interest to this study. It was desired to learn what types of research have been done and what findings have emerged. The second survey asks the same questions only with attention focused on three selected areas of study where it is suspected little use has been made of the instrumentation. Both of the surveys will seek to find either what has been done or what is being done in the areas searched.

Using the information found above as a point of departure, Chapter 4 will,also, seek to identify new research applications for instrumentation. Personal interviews with subject matter experts in three disciplines were arranged to assist in that process. Based on the research of Chapters 3 and 4, and on information gained in the interviews, charts were developed showing applications of instrumentation to research problems in the areas searched. Also, a coding system was developed to identify the types of application contained in the sources listed in the bibliography, to provide a convenient classification system for instrumented research (in this study and elsewhere), and to identify areas where the surveys indicate new applications of instrumentation might be made.

The final chapter will, first, describe an 'instrumentation resource center' type activity which could provide researchers and teachers in educational institutions with access to information and instrumentation appropriate to their needs. This activity would serve to bridge the information gap which exists between many researchers and the area of instrumentation technology.

The final chapter will, then, review the outcomes of the study, and present conclusions and suggestions for further research.

Chapter II

AN OVERVIEW OF AVAILABLE INSTRUMENTS AND TECHNIQUES

The purpose of this chapter is to develop two taxonomies, one of research instrumentation and one of research problems. The taxonomies contain instrumentation and research problems relevant to the fields of education, educational psychology, communication and other areas. The instrumentation taxonomy contains a continuum of instruments ranging from physiological (where measures are taken directly from the subject) to non-physiological (where measure are taken indirectly, e.g. by observation of the subject at a distance). This study will focus upon several of the physiological measures.

Comments on Taxonomy Development

Since this study presents two taxonomic structures to help achieve its objectives it is important that some problems related to the nature, strengths, and limitations of such structures be briefly addressed. During the literature searches a variety of articles and books were encountered in which 'taxonomies' of one sort or other were presented. Among those found there was some agreement on the definition of what a taxonomy is. Some sources first define the word according to its earliest etymology, its origin in the Greek words taxis (arrangement or classification) and nomos (law). Others do not stop to define the word but merely proceed to develop their structure in terms of what is needed for a particular application. In sum, though, the definition implied in the word 'taxonomy' is that of a science of classification according to certain laws and principles. In practice the rigidity of the word laws is sometimes softened to allow the term 'taxonomy' to be applied to 'convenient and useful schemata' which may contain some useful though occasionally arbitrary classifications.

There is some potential for misunderstanding in the building and use of taxonomies if one applies the meaning of 'taxonomy' used in certain of the natural sciences inappropriately in the social sciences. In biology and botany, for example, 'natural' hierarchies are recorded, e.g. kingdoms, phyla, superclasses, infraclasses, etc.. Those sciences have developed very detailed classification codes for themselves, e.g. The International Code Of Nomenclature For Cultivated Plants. Taxonomies encountered during this study in social sciences were based upon some observed natural divisions, some constructural content, and some categorizations which appeared to be prompted by the particular intentions of the author and by needs in the field of the author in organizing and displaying the information.

An example of a taxonomy developed for use in the social sciences is the Taxonomy Of Educational Objectives in the affective domain (Krathwohl, Bloom and Masia, 1973). The authors state:

> We should note that any classification scheme represents an attempt to abstract and order phenomena and as such probably does some violence to the phenomena as commonly observed in natural settings. The value of these attempts to abstract and classify is in their greater power for organizing and controlling the phenomena.... It was evident in our work that, although one could place an objective very readily in one of the three major domains or classes, no objective in one class was entirely devoid of some components of the other two classes. The domains evidently represent emphases and perhaps even biases in the statement of objectives.

It is important, therefore, that it be understood that taxonomies, such as those prepared for this study, represent a convenient way of organizing and displaying information. But the arrangement of instrumentation and research factors derives partly from norms arising from the nature of the information and partly from the needs of this study. Therefore, norms such as the principles of 'exclusiveness' or of 'natural hierarchy' cannot be used as the principal tests of the instrumentation and research factor taxonomies. The taxonomies have been developed for the purposes and requirements of this study and remain open to further development according to the needs of other researchers.

Development Of A Taxonomy Of Instrumentation

The taxonomy of instrumentation has been developed to provide an operational description of types of research instrumentation relevant to the needs of education, educational psychology, communication, and other fields, that are available. It lists and categorizes instruments ranging from simple and non-physiological (e.g. use of the technique of 'oral questioning' to get data) to more complex and physiological (e.g. use of skin conductance to measure affective responses).

The basic rationale for this taxonomy, the reasoning offered to justify its development, is based upon its usefulness in describing available instrumentation and upon its usefulness to researchers who wish to apply those tools in their work. In the words of Krathwohl, Bloom and Masia (1973): "...The value of these attempts to abstract and classify is in their greater power for organizing and controlling the phenomena...."

A variety of sources were consulted to determine the entries included in the taxonomy. None was found which attempted, systematically, to include the array of tools listed here in any sort of continuum. Especially, none was found which included physiological instrumentation in a continuum with non-physiological types. Such efforts may well exist in the literature but they were not located in the searches done for this study.

Finally, a word needs to be said about the arrangement and 'ordering' of instrumentation within the taxonomy. The listings fall into two main categories: instrumentation which is physiological (such as galvanic skin response), and those types which are non-physiological (such as various forms of standardized written examination).

The arrangement of the taxonomy with the physiological measures at the higher end of the list is based upon the fact that data taken with physiological instrumentation is taken directly from the research subject and is to some extent 'objectively' quantifiable in electrical, mechanical, etc., terms. Also, the difference in 'distance' between the research subject and the measuring instrument used leads to important differences in the type of distortion likely to occur in the data acquired. For example, studies have been done of the subtle movement of facial muscles during human interaction. There is a difference in 'distance' from the subject between having an observer scrutinize a video-tape for various movements as contrasted with direct measurement of the voltages appearing in those muscles during the same interaction. Both types of measure have advantages and disadvantages. But the distortion in data due to the limitations of the human observer are less easily definable than those introduced by a muscle voltage measuring instrument.

The taxonomy lists and categorizes instruments as: a) physiological or non-physiological and, b) where possible, in order of technological complexity, or complexity in format or materials required. Some of the listings in the taxonomy were arbitrarily assigned a place when no order was apparent since the primary purpose of the taxonomy is to display the instrumentation and techniques in a format useful to this study. To assist in defining the types of data and types of process relevant to each form of instrumentation columns have been included in the taxonomy describing the input to and processed output from each instrumentation type. In summary, the instrumentation taxonomy displays a broad range of available instrumentation and relates those to be focused upon in this study, categories 1 to 5, to others that are available. Further use of the taxonomy will be made later in the study.

TABLE 1

A Taxonomy Of Instrumentation For Data Gathering, Processing And Display

	Technique	Instrumentation	Input	Processed Output	Interpretations And Uses Of The Output
PHYSIOLOGICAL INSTRUMENTATION	**1. Electroencephalography**	electroencephalograph	bioelectric voltages on head surface picked up by surface or subcutaneous electodes: e.g. alpha and theta waves	voltages proportional to amplitude of brain voltages are recorded or used to produce audial/visual displays which vary with brain wave activity: voltages may be used to produce various command signals	categories 1 thorugh 5 of this chart deal with the techniques and instruments to be focused upon by this study. They are described at length in the definitions section of Chapter 1.
	2. Electromyography	electromyograph	muscle voltages picked up by surface or intramuscular electrodes	voltages proportional to amplitude of muscle voltages are recorded or used to produce audial/visual displays which vary with muscle activity: command signals may be produced	
	3. Galvanic skin response measurement (dermal conductimetry)	GSR meter (dermal conductimeter)	very small current from 1 lead of meter passed into skin surface then returned by a second lead to the meter	changes in skin conductance produce changes in the current which are amplified and fed out as meter readings, changes in the pitch of a tone, etc.	
	4. Biofeedback	biopotential translator (terms developed for this chart)	output of a biophysical instrument (e.g. 1 to 4 above)	sound, light, tactile stimulation, etc., proportional to the output of the biophysical instrument is provided to subject (biopotentials are translated to sound, etc.)	
	5. Biotelemetry	transmitter/medium/ receiver	transducers convert pressures, temperatures, accelerations, bioelectric potentials, etc., to currents or voltages which transmitter processes for the medium to be used (e.g. light, radio wave, sound, infra-red)	receiver converts signal to desired form, e.g. an analog or digital meter reading, or to changes in pitch of an audible tone	
	6. Plethysmography	plethysmograph	transducers convert changes in volume, circumference, etc., to currents and voltages (e.g. circumference of chest)	volume changes are displayed as meter movement, etc. When this method is used to record heart rate from the fingertip the device is called a cardiotachometer	a typical application is: measurement of the relative lightness or darkness of a fingertip (by passing light through and observing changes in intensity) to observe effects of stress in reducing peripheral blood flow

TABLE 1

continued. . .

	Technique	Instrumentation	Input	Processed Output	Interpretation And Uses Of The Output
PHYSIOL. INSTRUM.	7. Thermometry (physiological)	thermometer	a sensor (e.g. a thermistor, temperature sensitive metal strip or glass-mercury type) responds to temperature changes	temperature changes are converted to mechanical or electrical analogues proportional to the amount of change	measurement of temperature at various body locations is related to psychological and physiological arousal.
	8. Pneumography	pneumograph	transducer records physical changes related to rate and volume of air intake	meter readings (digital or analogue) display and/or record rate and volume of respiration	research relates respiration to attention, physical condition, to its role as a predictor of laughter, etc.
NON-PHYSIOLOGICAL INSTRUMENTATION	9. Pupillometery	film, videotape, etc.	changes in pupil diameter are recorded as various stimuli are presented	interpretation of changes is in terms of degree of change over time as related to the type of stimulus presented	this measure relates to response to pleasurable stimuli, to interest and attention. Two other eye measures using similar instrumentation are: blink rate (indicating general level of physiological arousal): gaze direction recording
	10. Feedback (general)	selected as appropriate e.g. print or oral format for feedback	behavior of subject serves as the cue to what feedback is appropriate	instructor, researchers, computer, etc., processes cues received and supplies feedback in the appropriate format	this category relates to many forms of feedback verbal printed, e.g. as used in programmed instruction
	11. Telemetry (general)	transmitter/medium/ receiver	speech, noise and other non-physiological data are processed and transmitted through the chosen medium (e.g. radio or wire)	receiver converts signal to desired form, e.g. sound or an analog meter reading	most social science research with this method appears to be to transmit speech rather than physiological or environmental variables
	12. Computer techniques	computer and associated hardware and software	data of any kind, to be processed, recorded	output can include print and graphic readouts, control commands for use in external systems	these techniques are useful in display, processing, recording, controlling and managing of instruction
	13. TV techniques	video system components	data, e.g. visuals, to be processed, recorded	output can consist of video display of print, graphic, photographic, etc. information: as in audio techniques the rate of display is variable	research with TV includes study of response to the medium itself (e.g. to picture or sound quality), its use as a mediator of information
	14. Photographic techniques	camera, projectors, etc.	print, graphic, and other images are recorded, e.g. in the form of still pix, slides, movies	output consists of projected or printed analogue of subject and is determined by film used, e.g. color, black and white, infra-red	these techniques have been extensive researched and for most instructional settings comprise the most sophisticated form of technique employed

TABLE 1

continued...

NON-PHYSIOLOGICAL INSTRUMENTATION

Technique	Instrumentation	Input	Processed Output	Interpretation and Uses Of The Output
15. Audio techniques	recorders, amplifiers, etc.	transducers convert sound or vibration into an electrical analogue of the sound	information can be amplified, recorded, played back, expanded or compressed in rate, etc.	these techniques, like the above have been extensively researched and applied
16. Other Audial-Visual techniques	sound-to-light translators, audio synthesizers, etc.	electronic circuits process audio fed into them or generate new sounds	output may be the desired end product or can be used to drive other circuitry, e.g. sound-to-light translators	the potential of these tools is in the process of being identified. Little research is available regarding them.
17. Verbal/Interpersonal techniques and formats for data gathering	interview format, simulation, games, group discussion, etc.	verbal, and other, input provided by participants in the format	desired observations, e.g. on communication behaviors, verbal content, attitudes	considerable development has occurred in use of some of these methods in recent years. Applications are being made in education, communications and other fields
18. Print, standardized, etc., techniques and formats for data gathering	tests, scales, questions, surveys, whether written, oral, tactile, or mediated (e.g. by computer): for achievement, comprehension, intelligence, personality, biography, interest	written, verbal and other input provided by participants in the format	desired data and observations, e.g., on content of written responses	these, like the above, are in common use. They have begun to be used, however, in conjunction with physiological measures such as those in categories 1 to 9. This provides a corroborative test of their results
19. Chronography	mechanical or electronic time measuring and/or displaying instruments, e.g. clock or stopwatch	electronic or mechanical power sources power oscillatory systems	electronic output in digital or analog meter form, or mechanical output with analog dial or meter output: a command signal may be developed for use externally	this measure has long been in common use. Recent technological developments, however, greatly increase the accuracy with which measurement of time elapsed can be done, e.g. digital stopwatches
20. Quantification techniques e.g. counting techniques	event counting and/or displaying instruments, mechanical or electronic: e.g. for counting how often a behavior occurs; amount amplitude or degree measuring and/or displaying instruments, e.g. displacement, force, velocity	external events produce a cumulative count in an instrument or electrical or mechanical analogues of external events	accumulated count or changes in external are displayed: a command signal may be generated to initiate external events	the same comments made above apply to the types of instruments described in this category
21. Environmental measurement techniques	instruments for sound level, light, temperature, vibration level, atmospheric pressure, relative humidity, etc.	variations in the appropriate environmental variable	analog or digital indications of the state of the variable	some of these measures have been explored in connection with communication and educational situations. Others, such as barometric pressure and its effects on attention, on 'feeling bad', on unusual animal behavior prior to storms, earthquake, etc. have been less explored.

As mentioned earlier the principal divisions in the taxonomy are: a) physiological and non-physiological instrumentation, b) technology of higher complexity, producing data in which some of the distortion is 'objectively' quantifiable, versus technology of lower complexity, producing data in which quantification of distortion is more difficult. As predicted, some of the listings were arbitrarily assigned higher positions in the taxonomy where no clear precedence in complexity was apparent. A description of some of the kinds of input which are utilized and of some of the processing which occurs within instrumentation has been included. Such details are helpful in the differentiation of instrument types. Also, they will provide some of the groundwork for later development (not in this study) of a more thorough description and philosophical study of instrumentation.

Development Of a Taxonomy Of Research Problems (Factors)

The taxonomy of instrumentation attempts to classify and describe some of the types of instrumentation that are available for research. To help in showing applications of the instrumentation listed, particularly the roles of newer, less known, instrumentation, it was decided that it would be useful to include a taxonomy of research problems, or research factors. Such a taxonomy, used in conjunction with the instrumentation taxonomy, provides a scheme in which one can see clearly the range of available instrumentation displayed opposite the range of potential research problems. This section will provide such a juxtaposition of the two taxonomies. Practical applications of this type of arrangement are made in Table 3 and in Chapter 4, where it will be used as a vehicle for displaying the results of this study and for display of a coding system which identifies the contents of this study's bibliography.

The taxonomy of research factors was developed through a search of literature in psychology, education and other areas. Two sources which proved useful were: a) The Thesaurus of Psychological Index Terms (1974), an alphabetical index of psychological terms developed for use with the Psychological Abstracts computer system (Appendix A describes a Psychological Abstracts search made for this study). Some terms describing research problems related to the fields of education, communication and educational psychology were selected out of this source: b) The Thesaurus of Eric Descriptors (1975), an alphabetical listing developed for use with the ERIC (Educational Resources Information Center) computer system (Appendix A describes two ERIC searches made for this study). Once again, terms describing research problems related to the fields of education, communication and educational psychology were selected out of the listings.

As a convenient framework within which to list groupings of research problems three categories are used: cognitive/intellectual problems, affective/emotional problems, and psychomotor problems (sensory perception was placed under this heading although it is related to both of the other categories). The categories of cognitive, affective and psychomotor were used for a different purpose (categorization of educational objectives) by Krathwohl, Bloom and Masia (1973).

This juxtaposition of the two taxonomies makes it possible to select a research factor from the research factor taxonomy and then to search the instrumentation taxonomy to identify the range of tools applicable to that factor.

TABLE 2

A Research Problem Taxonomy Juxtaposed With
The Instrumentation Taxonomy

Taxonomy Of Research Factors

I. Cognitive, Intellectual Factors (Note: Sec I, II & III overlap depending on the research being done)

Ability, achievement, attention (span, etc.), attitudes (nature of, content, formation, change), beliefs, cognitive learning style, concentration, judgment, learning, forgetting (mechanism and rate of), motor skill learning, non-verbal learning, opinions, transfer of learning, trial & error in learning, verbal learning.

II. Emotional, Affective Research Factors
Emotional development, maturity, adjustment, control, emotional-intellectual response parameters (amplitude, duration, frequency, generalization, latency, sets, time, variability), emotional states (anxiety, aversion, boredom, confusion, doubt, fatigue, fear, frustration, panic, pleasure, stress, tension), personality traits.

III. Psychomotor, Physiological Research Factors

A. General physiological factors: body movement (gross or minute, e.g. types, patterns frequency, speed, etc., as in subvocalization, non-verbal communication, etc.) development (growth, maturity), environmental factors (physical adaptation, to temperature, radiation, deprivation, etc.), fatigue, motor measurements (e.g. level of performance in manual skills, walking, running, working), muscle factors (tension, tone, pressure exerted, e.g. in writers cramp), psychomotor processes (fine or gross motor skill learning processes (e.g. agility, dexterity, coordination).

B. Sensory Perception:
1. Visual perception: acuity, discrimination (of color, space, distance, size), distortion, eye movement (frequency and direction of), blinking, pupillary response, reading (ability, comprehension, speed), visual attention, visual feedback (forms, effects and value of).

2. Auditory perception: auditory sense & attention, concentration, feedback (forms, effects and value of), auditory stimulation effects, discrimination (pitch, loudness, location, quality, thresholds), masking effects, noise, sensitivity, speech (structure, perception and processing)

3. Touch, taste and smell: smell and taste (effects of stimulation, qualitative judgments: e.g. good-bad, strong-weak, qualified gradations), touch (effects of stimulation through pressure, temperature: qualitative judgments: e.g. hot-cold, light-heavy, smooth-rough, present-absent).

IV. Various Factors Which May Require Measurement

A. Frequency of occurrence of an event in a specified time period (e.g. the number of problems worked per minute). This a 'rate'.

B. Sum total of events occurring (e.g. a student worked ten problems correctly).

C. Tabulation of qualitative aspects of data (good-bad, right-wrong, etc.).

Instrumentation & Techniques for Data Gathering, Storage, Processing and Display

1. Electroencephalography (EEG): brain voltage measurement, e.g. alpha & theta
2. Electromyography (EMG): muscle voltage measurement
3. Galvanic Skin Response (GSR): skin conductance measurement
4. Biofeedback techniques: visual, auditory, tactile, smell, taste, etc.
5. Biotelemetry techniques: physiological data transmitted by radio, wire, light, sound, infra-red, etc.
6. Plethysmography: girth & volume measurement, e.g. to measure amount of blood flow in finger tip during stress
7. Temperature measurement of various body areas: e.g. as a measure related to stress or motor activity
8. Respiration measurement: observation of changes in rate, volume, etc.
9. Pupillometry: Observation of changes in pupil diameter during affective responses, e.g. to taste, smell
10. Feedback techniques (non-physiological): provision of verbal, printed, etc., feedback, e.g. in programmed instruction
11. Telemetry techniques (non-physiological): e.g. to transmit language patterns
12. Computer techniques: e.g. for display, processing, recording, controlling and managing instruction
13. TV techniques: e.g. for mediating instruction
14. Photographic techniques: e.g. slides, still pix, movies, study of affective response with infra-red film (light or dark images from warm or cool surface)
15. Audio techniques: e.g. to record, play, expand or compress rate
16. Other Audial-Visual techniques: e.g. sound to light translators, audio synthesizers
17. Verbal/Interpersonal techniques and formats for data gathering: e.g. group discussion, simulation, games
18. Print, standardized, etc., techniques & formats for data gathering: e.g. tests, scales, surveys: written, oral, tactile, etc., for achievement, comprehension
19. Chronography: mechanical or electronic time measuring instruments
20. Quantification techniques: e.g. counting, indication of amount, amplitude, degree, displacement, force, velocity
21. Environmental measurement techniques: e.g. sound level, light, temperature, vibration level, atmospheric pressure, relative humidity

A practical application of Table 2 is made in Table 3 where a single research factor, 'motor skill learning', is listed opposite the instrumentation taxonomy.

TABLE 3

Application of the Research Factor Taxonomy to a Research Problem

		Taxonomy of Instrumentation for Data Gathering, Processing And Display
1. For this example the research problem for which instrumentation is needed is 'motor skill learning'.		1. Electroencephalography (EEG): brain voltage measurement, e.g. alpha & theta
	✓	2. Electromyography (EMG): muscle voltage measurement
2. A check-mark is placed next to each type of instrument which might be applied to motor skill learning. You will note that for this problem nearly all the instruments listed might, depending on circumstances, be relevant.	✓	3. Galvanic Skin Response (GSR): skin conductance measurement
	✓	4. Biofeedback techniques: visual, auditory, tactile, smell, taste, etc.
	✓	5. Biotelemetry techniques: physiological data transmitted by radio, wire, light, sound, infra-red, etc.
3. A verbal description of how a few of the instruments might be used is now given.		6. Plethysmography: girth & volume measurement, e.g. to measure amount of blood flow in finger tip during stress
Muscle voltage measurement can provide measurement of level of exertion, aid in evaluation of performance, aid in training for muscle relaxation.	✓	7. Temperature measurement of various body areas: e.g. as a measure related to stress or motor activity
	✓	8. Respiration measurement: observation of changes in rate, volume, etc.
Galvanic skin response measurement can record arousal level during confrontation with and performance of a motor task. Also, it can aid in conditioning for relaxation when confronted with anxiety producing tasks or the need for high levels of performance.		9. Pupillometry: Observation of changes in pupil diameter during affective responses, e.g. to taste, smell
	✓	10. Feedback techniques (non-physiological): provision of verbal, printed, etc., feedback, e.g. in programmed instruction
	✓	11. Telemetry techniques (non-physiological): e.g. to transmit language patterns
Biofeedback techniques can be used in optimizing motor performance through conditioning of muscles for efficient motor output.	✓	12. Computer techniques: e.g. for display, processing, recording, controlling and managing instruction
	✓	13. TV techniques: e.g. for mediating instruction
Biotelemetry techniques will allow monitoring of performance in a variety of natural settings.	✓	14. Photographic techniques: e.g. slides, still pix, movies, study of affective response with infra-red film (light or dark images from warm or cool surface)
	✓	15. Audio techniques: e.g. to record, play, expand or compress rate
The other forms of instrumentation which have been check-marked each offer their unique capabilities. The choice of instrumentation will be based upon the particular needs of the researcher	✓	16. Other Audial-Visual Techniques: e.g. sound to light translators, audio synthesizers
	✓	17. Verbal/Interpersonal techniques and formats for data gathering: e.g. group discussion, simulation, games
	✓	18. Print, standardized, etc., techniques & formats for data gathering: e.g. tests, scales, surveys: written, oral, tactile, etc.: for achievement, comprehension
	✓	19. Chronography: mechanical or electronic time measuring instruments
	✓	20. Quantification techniques: e.g. counting, indication of amount, amplitude, degree, displacement, force, velocity
		21. Environmental measurement techniques: e.g. sound level, light, temperature, vibration level, atmospheric pressure

Use of the instrumentation taxonomy in the manner demonstrated in table 3 will require some knowledge of the function and applications of the instruments listed. For most users of instrumentation consultation with knowledgeable persons will be necessary. One of the purposes of this study, however, is to provide an introduction to such functions and applications, though specifically for the first five categories of instrumentation.

It will be noted that in the research factor taxonomy some factors might have been listed under more than one of the three major headings, e.g. eye movement observation as used in research concerned with the level of physiological arousal of subjects. Although the taxonomy is not exhaustive or definitive in its presentation of research factors it is adequate for the purposes of this study. As mentioned earlier a practical application will be made in Chapter 4 of the juxtaposition of instrumentation versus research factors. In that case the listings are not taxonomic but, rather, narrowed down for the specific purposes of the study.

This chapter has provided an introduction to a wide range of research problems and instrumentation. The following chapter will narrow its focus and show research applications made of the first five instruments listed in the instrumentation taxonomy.

Chapter III

THE MULTI-DISCIPLINARY REVIEW OF THE LITERATURE

This chapter will accomplish the fourth of the seven objectives of the study: to determine who, in general, uses the types of advanced instrumentation to be focused upon by the study, how it is used, and with what results.

As stated in chapter 2 the instruments and techniques being focused upon are:

1) Brain wave monitoring instruments (specifically those measuring alpha and theta waves)
2) Skin conductance monitoring instruments (galvanic skin response)
3) Muscle voltage monitoring instruments (electromyographic measurement)
4) Biofeedback techniques
5) Biotelemetry techniques

The survey of literature showed that the first three of the above categories of instrumentation are commonly used in conjunction with biofeedback techniques. Accordingly, this section deals, first, with research applications involving those instrument types with biofeedback. It should be noted that the three instrument types are _not_ always used with feedback to the subject. Next, survey results concerning telemetry will be presented. Telemetry is treated separately because the survey shows that it is an underused research tool. None of the citations found in social science sources reported its use to transmit biological information. Reasons why telemetry is not commonly used by researchers to transmit either biological, or non-biological, data will be discussed.

For the convenience of the reader a chart has been included to allow a rapid review of the research reported in this chapter. This chart lists research in the order in which it appeared in the chapter.

In the final section of the chapter the results of the multi-disciplinary survey are summarized.

Results of the Multi-Disciplinary Survey Of Literature

This section begins with a caution, expressed by a psychotherapist, Birk (1973):

> It is my own belief that biofeedback has already been proven to have very considerable clinical value in certain clinical situations... and it seems, also, to have great promise in some other areas, but that it is in clear danger of being oversold, to the point of counter-movement revulsion, unless balance can be reintroduced.

This citation is presented first in the review of the cross-disciplinary survey of literature because popular and professional literature does, indeed, contain a wide variety of assertions about the use of biofeedback and instrumentation. At this time in the development of instrumentation technology the reader must exercise caution in forming opinions as to what is to be accepted as sufficiently substantiated by research. The above citation was taken from a journal issue which contains one of the most thorough treatments of biofeedback, and associated instrumentation, found in the survey of literature done for this study. A researcher planning to use feedback techniques and instrumentation will find it useful (see Birk, 1973).

Instrumentation and Biofeedback In Education. Mulholland (1973) states that many biofeedback researchers have already demonstrated the potential value and uses of their technology for education and that it's now time for educators to take advantage of it. He asserts that through creative and intelligent application of the new biofeedback technology the educational community may achieve major advances in the processes of communicating, teaching and training. He points out that one of the obvious potential uses of biofeedback techniques is 'attention', the basic requirement for learning. In his laboratory, prototype systems exist "with which children can view television, film-strips, or light shows, regulated by their control of their own alpha rhythm, or visual attention (1973)." With such displays, which are sensitive to the level of attention of students, Mulholland claims that a variety of reinforcements can be built in and alternate paths for instructional presentation included. The role of such methods in development of instructional strategies remains uncertain, however.

Lavach (1973) reports research in which galvanic skin response (skin conductance measurement) was used by him in research investigating whether learners have better memory recall when the learning was done in a state of high arousal. He states that his research supports that hypothesis.

> ...forgetting occurs under low arousal conditions while a strong reminiscence effect is observed if acquisition is accomplished under high arousal. It appears, then, from the present, as well as cited, research, that educators must reexamine their priorities in any given learning situation. Evidence seems, in general, to support the notion that antecedent behaviors exert an important control over the formation of correct associations during the learning process. This further suggests that emotional arousal, novel stimuli, questions, and a myriad of other variables may affect the acquisition and retention of a response (1973).

Fisher and Kotses (1974) used galvanic skin responses in investigating responses of research subjects to differences in the sex of the researcher. Galvanic skin response measurement indicates that subjects participating in research show significant differences in their physiological response to the researcher if the researcher is of the opposite sex. Such research suggests that the sex of a teacher may have some effect on arousal level of learners. Other paralells in education and communication might be found.

Shapiro and Schwartz (1972) point out that the application of biofeedback to processes germane to education and learning has been suggested. They describe research in which retarded children, rewarded with candy for producing GSR orienting responses to stimuli of different visual forms, improve their performance on form-board tasks. They point out that this is an influencing of the physiology of attention and that "the goal here is to use the feedback training to increase attention and therefore increase transfer of learning (1972)." They describe research with alpha feedback which is attempting to influence 'creativity' through generation of mental reverie states in which hypnagogic imagery (pictures or images that come to mind but are not consciously or deliberately generated) is produced.

Woodruff (1975), a psychologist, reports her research in which the relationship between alpha wave production and reaction time was studied. She suggests that higher rates of brain wave activity appear to be accompanied by faster reaction time. Plotkin (1966) reports research in which subjects are given different sorts of instructions while their alpha production is being monitored. Some received instructions addressed to cognitive activities in the subject, e.g., they might be told to relax. Others received instructions related to oculomotor activity, e.g., blur your vision or focus your vision. This research explores the reasons why oculomotor activity can cause alpha wave production to 'block' or stop.

This type of research is related to such educational problems as 'attention' and 'concentration.'

A study showing the effects of monetary rewards on alpha production was done by Kondo, Travis and Knott (1975). It was found that subjects offered rewards of $5 and $10, as compared to subjects offered $5 or no reward at all, produced significantly more alpha. From the point of view of the educator use of incentives to increase motivation to work and learn is an area of great interest.

Danskin and Walters (1973) point out that while Skinner's behavioral engineering by external controls has been receiving much attention, the last few years have seen the development of biofeedback and the concept of self-regulation of one's own psychological and physiological processes. They feel this represents a breakthrough to truly voluntary self-regulation, with social and philosophical consequences. Also, biofeedback use may lead to keeping of each student's physiological record in order to provide truly individually adapted programs based upon each student's patterns of alertness and attention, cognitive style and special skills. Danskin and Walters claim that the effects of self-regulation in individuals will be of incalculable significance. They state that persons with voluntary control over their own behavior would not only NOT be a problem, but they would also make it easier for others to attain a more stable and yet creative life.

Toomin and Toomin (1973) state that the value of biofeedback instruments is that they provide an immediate indication of relevant internal cues associated for each individual with a particular physiological condition. The person may then follow the path of these cues to reach the desired altered state of being. They point out that this is a self-regulated process, an active one, as opposed to the passive process involved in 'pill-popping'. This self-regulating aspect of biofeedback is the same factor that Danskin and Walters feel is so important. Toomin and Toomin make another pointed observation. Since biofeedback is based upon self-regulation, on enhancing natural processes, on inward focusing and on perceiving man as a mind-body unit, then a popular conception comes under question, the claim that technology de-humanizes people. They state: "At a time when technology and humanism seem to be pulling in different directions, biofeedback provides man with a way to use technology in the most personal ways possible - to lead to self-discovery, self-awareness, self-control, and self-determination (1973)."

Blanchard and Young (1974) describe research in which biofeedback of muscle tension and brain waves was used in an effort to relieve college students of test anxiety. On the post-treatment assessment on one study "the experimental group showed less test anxiety as measured by the questionnaire ($P<.01$) but did not differ on the performance measures or on end of term grades." They describe another test anxiety research project in which "The case was successful as the patient passed an examination that she had avoided even taking several times because of high anxiety levels." Blanchard and Young, after presenting a thorough review of the types of biofeedback research that has been done, sound a warning. They point out that solid research is needed before some of the claims being made for biofeedback can be evaluated. They state that some poor research has been done and that some claims are being made which do not find support in available research.

Instrumentation And Physical Education. In the field of physical education an important area of research is kinesics, or kinesiology, the study of bodily movements and muscle activity. Electromyographic, and other measures have been used in that area. Cavanaugh (1974) describes some of the research questions asked and cautions against potential misinterpretations of the information gotten from electromyographic measurements in that area.

As will be discussed in the section on telemetry, application of electromyographic, cardiac, and other measures are being made in conjunction with telemetry techniques, e.g., to monitor the activities of swimmers while diving and while in the water.

The science of kinesiology involves a variety of measures but the cross-disciplinary survey of the literature produced few citations relating to that science or to the field of physical education.

Instrumentation and Counseling. Danskin and Waters (1973) were described earlier as pointing out that biofeedback training "stands out as a real breakthrough to truly voluntary self-regulation with philosophical and social consequences (1973)." They state, further, that professional literature in counseling and education "is nearly devoid (1973)" of even casual reference to biofeedback training for self-regulation and self-development. One of the most important considerations for counselors is that there are a variety of useful consequences arising from the control by individuals of certain states and processes. Danskin and Walters emphasize that "this is the real impact of biofeedback - man's enhanced sense of worth, self-reliance, and autonomy (1973)." This, they argue, is sufficient reason for exploration of such techniques by persons involved in counseling in education.

Henschen (1976), a counseling psychologist, reports using biofeedback training to stimulate the unconscious of subjects during counseling. Patients are taught to increase their theta brain waves (waves in the 4 to 8 hertz, i.e., 4 to 8 cycles per second, range). This wave is normally produced when a person is drowsy or nearly asleep. Henschen states that

> ...people undergoing theta training frequently report seeing images of faces, people, animals, geometric shapes, colors and lights. These images just seem to spring into awareness (1976).

Henschen encourages patients to confront their imagery directly and dialogue with it, expressing "the immediate feelings he or she has toward the confronted object (1976)." This approach may substitute for use of drugs in some counseling situations. Henschen uses electromyographic feedback, also, in inducing relaxation during counseling.

Instrumentation and Reading Education. Danskin and Walters (1973) describe the application of biofeedback to the problem of subvocalization, the tendency to mouth words silently while reading. Using electromyography and feedback (measuring larynx muscle voltages, then presenting a sound to the subject based on those voltages) "helps most subvocalizers overcome the habit in from one to three hours (1973)." Blanchard and Young (1974) describe how "Hardwyck, et al., reported on a rapid treatment technique utilizing EMG feedback... In one 30 minute feedback session the entire sample of 17 subjects reduced EMG activity to baseline (at rest and not reading) levels. Most subjects showed complete reduction within the first five minutes. Follow-up tests at one and three months with no feedback showed no return of subvocalization." They cite other studies in which attempts were made to supress subvocalization, without the use of biofeedback, which were unsuccessful.

Instrumentation And Research In Intelligence. Some research is being done to learn whether production of alpha waves can be somehow related to the intelligence of research subjects. Ellingson and Lathrop (1973) state that "the rationale for exploring a possible relationship between alpha frequency and intelligence lies in the evidence that the alpha rhythm may reflect a cerebral gating or excitability cycle... Higher alpha frequencies might therefore reflect more rapid information processing, and this, in turn, would be reflected in improved performance in at least some of the operations which are conceived to be related to the construct 'intelligence' (1973)." Toomin and Toomin (1973) cite other research which provides "some slight evidence that increasing the percent of alpha and its amplitude has some positive effect on mental efficiency (1973)." This type of research is of direct interest to researchers in the social sciences and other research areas.

Instrumentation and The Hyperkinetic Child. Work is being done to determine whether alpha training might affect the behavior and performance of hyperkinetic children. Nall (1973) found in research with such children that alpha could not be claimed to produce a reduction in the hyperkinetic syndrome, although some temporary relaxing effects were achieved. Such training also failed to cause measurable gains in achievement in such children. As for whether alpha produced any unique effects for these children, the results are inconclusive.

Instrumentation and Instructional Technology. Knirk and Spindell (1975) relate use of instrumentation and biofeedback techniques to applications in the field of instructional technology.

> One of the newer techniques of measuring the effects of instructional methodology relates to a class of measurements called "indirect (biofeedback) measures" of behavioral change and/or learning. These indirect indices include those measured by the electroencephalograph (EEG), electrocardiogram (EKG), galvanic skin response (GSR), heart-rate, blood pressure instruments, voice analyzers and blood analysis tools. These measures can provide useful data for the educator concerned with designing learning environments and associated instructional materials.

They point out the potential usefulness of such measures in individualizing of instruction. If it is possible to determine a learner's state of awareness, whether alert, tired, bored, anxious, etc., then a large part of the message loss could be avoided. They suggest that using instrumentation to determine the points at which a learner begins to become bored, at one extreme, or unduly pressured, at the other, might enable the instructor to better 'individualize' instruction for that person. Such a determination might be made through monitoring of three categories of brain waves; 1) theta waves: produced when a subject is very relaxed, near sleep, sometimes experiencing hypnagogic (spontaneously arising) imagery, 2) alpha waves: produced when a subject is relaxed but alert, 3) beta waves: produced when a subject is at a high level of mental arousal, perhaps due to stress. Knirk and Spindell (1975) feel, once again, that there is usefulness in measuring the above states so that instruction can be adapted to the state of mind of students.

Instrumentation and Medicine, Psychiatry and Psychology. Shapiro and Schwartz (1972) report that some use is being made of biofeedback instrumentation for clinical purposes and that "initial exploratory work... leads us to feel optomistic about the possibilities (1972)." They describe work with hypertension, cardiac arrhythmias, tension headaches and other psychophysiologic disorders. In treatment of snake-phobic subjects, where subjects were rewarded for controlling their GSR (skin conductance) while being shown pictures of snakes, they write that "data suggested that subjects could gain some control over their physiologic responses to fearful stimuli in a single session, and that this was accompanied by a relative decrease in fear as indicated by a post-experimental questionnaire (1972)." They describe, also, clinical applications of alpha feedback or self-regulation and relaxation.

Plotkin and Cohen (1976), psychologists, describe research into the nature of the "Alpha experience', that is, the psychological and physiological correlates of the pleasant feelings and relaxation which accompany increased production of alpha waves. Sterman (1973) reports his research into the psycho-physiological bases of alpha activity.

Coursey (1975) details some applications made of electromyography.

> (Some applications are)... enhancing the control of voluntary muscles where that control has either not been developed (Scull & Basmajian, 1968) or where it is diminished through dysfunction (Harrison & Connolly, 1971). The second area consists of attempts at achieving low levels of muscle tension (Green, Walters, Green, & Murphy, 1969) with patients who experience chronic tension headaches (Budzynski, Stoyva, & Adler, 1970) and chronic anxiety (Raskin, & Johnson, Rondestvedt, 1973). Other possible uses include the treatment of bronchial asthma (Davis, Sanders, Creer and Chai, 1973), insomnia (Raskin, et al., 1973), or any disorder that is associated with muscle tension.

Coursey (1975) conducted research using electromyography. He states that the research "showed rather clearly that EMG feedback is more effective in lowering tension in a specific muscle throughout training than either simple verbal instructions or the reduction achieved by the subject's own unaided efforts." He states, however, that generalization of the relaxation to other muscle masses in the body does not occur, and that to date the relative value of EMG in comparison with other relaxation techniques is not yet clear.

Applications of Biofeedback With Instrumentation Other Than That Focused Upon By This Study. Heart rate: a subject's heart rate can be detected by use of a microphone, photocell, electrodes or cuff. Some subjects, given feedback,have been able to exercise remarkable control over the rate.

Sexual function: Using photocells, temperature sensors, and various electro-mechanical arrangements, along with feedback of sound, etc., to the subject, researchers claim that control over some aspects of sexual function has been achieved (Laws and Rubin, 1969; Henson and Rubin, 1971).

Applications of Telemetry Instrumentation to Research

As defined in Chapter 1 'telemetry' means to measure at a distance. Sound, bio-electric activity, temperature, or any other measurable quantity can be transmitted by radio, wire, sound, etc., to a point miles away or inches away. When telemetry is used to transmit biological activity it is called 'biotelemetry'. Such transmitters can be smaller than the circumference of a pencil. The most commonly available types, sold in popular electronic stores, are about the size of a package of ciagarettes. They make possible the relatively unobtrusive monitoring of research activity.

Hoshiko and Holloway (1968) state that the cost and availability of instruments indicate that speech and language research with radio telemetry is now possible. "We are able to demonstrate the feasibility of collecting verbal data from a preschool child in his everyday environment using inexpensive, readily available, radio equipment." They emphasize the value of telemetry in conjunction with the type of instrumentation described in the first part of this literature survey: "Of greater interest than the data was the feasability of a telemetry system consisting of inexpensive, readily available radio instruments. An extension of this technique into the telemetering of physiological data during speech activity offers further research and clinical observation of verbal behavior in a natural setting." Hoshiko and Holloway (1968) provide a discussion of what is needed to do research with telemetry. This should be useful to researchers setting up a system. Miklich, Purcell and Weiss (1974) also provide a thorough treatment of what a researcher needs to know and do in planning for experimentation with telemetry. Frampton, Riddle and Roberts (1976) describe a system for telemetering physiological information from swimmers both when they are in and out of the water. This makes possible study of the swimmer's physiological activity during dives, various types of strokes, etc. They state that the system described will be commercially available.

Swain (1970) used telemetry to study the arousal responses of students to specific structured classroom activities and events. He found, through telemetry of cardiac rate and amplitude that:

> ...Students can be aroused physiologically as a result of experiencing certain structured classroom activities and events.
> ...Classroom situations which provide for the interaction of student and teacher create a more arousing environment than does a situation in which the student is passively involved (e.g., listening to a lecture)
> ...Students become physiologically aroused in an interaction type of classroom situation even though they, themselves, are not overtly interacting with the teacher or with other students.
> ...Students become more physiologically involved... when placed in a classroom situation in which they know they are expected to participate overtly... (1970).

N. H. Pronko (1968) states that biotelemetry offers greater controls for man or beast, and that "in the same way as the jet is superseding the wheel (at least the propellor), so the wire is obsolescent in light of the technological advances being made with the wireless (1968)." He suggests its applicability in studies ranging from remote monitoring of the results of operant techniques (e.g., transmission of data that a rat wants to push the lever will be sufficient data) to use with children in school or the playground. Pronko describes (1969) potential applications in measurement of EKG, EMG, EEG, pH, blood pressure, gastronintestinal pressure, movement, pressure, temperature, foetal heartbeat and infant toilet training.

Drinkwater and Flint (1968) report using telemetry in measurement of eye blink rate as an index of generalized muscular tension. Grunewald-Zuberbier, Grunewald and Rasche (1972) have done research using telemetric measurement of motor activity in maladjusted children in play situations, in task-free waiting situations, and in a task-structured situation. Rugh (1971) describes a telemetry system for measuring chewing behavior in humans.

Hanley (1976), a physician, emphasized the underuse of telemetry in medical and other research.

> Biotelemetry has been underused in medicine in the past and present at all levels: human clinical monitoring on a routine basis, basic and clinical research in man and the experimental animal, and in the every-growing necessity of the understanding of the medicine of health and prediction of disease which would make prevention a possibility and preparation a certainty (1976).

Moos (1968) emphasizes the importance of the careful evaluation of the behavioral effects of being observed. He studied the reactions of subjects to being observed while carrying telemetry transmitters.

Soskin and John (1963) used telemetry as a data collecting medium using two husband-wife pairs in a vacation setting. Purcell and Brady (1966) monitored vocal behavior of 13 adolescents in a cottage environment. Herron and Ramsden (1967) describe research using telemetry in which overt human body movement was monitored. They observed "such behavioral phenomena as gestures, tics, motor learning, "relevant" and "irrelevant" motion, "activity" patterns, laterality and motor skills, among others (1967)."

Nordquist (1971) used telemetry and videotape to observe and record verbal behavior in free play settings. Gardner (1973) used telemetry in research evaluating speech and language patterns in preschool children. She describes potential applications of telemetry techniques:

> Radio telemetry is a highly dependable scientific tool in the study of communicative disorders of most age groups, whether for clinical application (such as evaluation or carry-over), developmental study (such as language, stuttering, or voice), or experimental research (such as control situations without experimenter intrusion), (1973).

Listing of Research Applications Identified in the Multi-Disciplinary Survey

For the convenience of the reader the research described in this chapter will now be presented in chart form. The research and applications are listed in the order in which they occur in the chapter. A breakdown of the research located for the whole study into categories of instrumentation versus application is accomplished by the coding chart in chapter 4. That chart provides a code for the bibliography so that research and applications relating to a particular instrumentation type can be identified and located.

Table 4

Summary of Research Applications of Instrumentation Identified in the Multi-disciplinary Literature Search (Listed in order of appearance in this chapter)

Research Applications	Author(s)
Clinical use of biofeedback	Birk 1973
Educational use of biofeedback (in teaching, training, communicating, study of attention, reinforcement, instructional design)	Mulholland 1973
Use of galvanic skin response to study arousal, memory recall	Lavach 1973
Use of galvanic skin response to study effects of differences of sex of researchers upon research subjects	Fisher & Kotses 1974
Use of biofeedback in researching retardation, reward vs. performance, attention, creativity; clinical use of biofeedback	Shapiro & Schwartz 1972
Use of alpha waves in study of reaction time vs. age	Woodruff 1975
Study of the value of various kinds of instructions in affecting amount of alpha produced	Plotkin 1976
Effects of monetary reward upon alpha production	Kondo, Travis, Knott 1975
Study of biofeedback in self-regulation of psychological and physiological processes, e.g. EMG in regulating subvocalization	Danskin & Walters 1973
Biofeedback as a cue to learning self-control, contrasted to drugs, humanization of technology; effects of alpha production on mental efficiency	Toomin & Toomin 1973

Summary of Research Applications continued....

Research Applications	Author(s)
Biofeedback and reduction of muscle tension and test anxiety; thorough review of field of biofeedback research; EMG and subvocalization	Blanchard & Young 1974
Use of electromyography in the area of Kinesiology: muscle activity, body movement, etc.	Cavanaugh 1974
Use of biofeedback of Theta waves as an aid to producing imagery during counseling sessions	Henschen 1976
Study of relationship between alpha production and intelligence	Ellingson and Lathrop 1973
Study of the effects of alpha training upon hyperkinetic children	Nall 1973
Use of biofeedback in measuring behavioral change, learning; importance of instrumentation to instructional technologists; use of instrumentation in measuring fatigue, alertness, anxiety; individualization of instruction based on knowledge of the above	Knirk & Spindell 1975
The nature of the 'alpha experience', pleasantness & other subjective responses to it	Plotkin and Cohen 1976
The psycho-physiological bases of alpha activity	Sterman 1973
Enhancement of muscular control through use of EMG feedback; EMG use with headaches, anxiety, asthma, insomnia & other conditions related to muscular tension	Coursey 1975
Use of biofeedback in affecting heart rate, sexual function	Laws & Rubin 1969, Henson & Rubin 1971

Summary of Research Applications continued....

Research Applications	Author(s)
Use of telemetry in language research: speech patterns, physiological activity during speech; unobtrusiveness in research; practical problems and solutions	Hoshiko & Holloway 1968
What researchers need to know to plan and implement use of telemetry in their research	Miklich, Purcell, Weiss 1974
Telemetering physiological information from swimmers	Frampton, Riddle, Roberts 1976
Use of telemetry to study arousal of students in specific structured classroom activities; relative arousal resulting from different instructional strategies	Swain 1970
Use of telemetry for unobtrusive gathering of physiological and other data, e.g. from children in playground	Pronko 1968
Use of telemetry in study of behavior; discussion of reasons for limited use of telemetry techniques by researchers	Schwitzgebel 1964
Telemetric measurement of motor activity in maladjusted children during play	Grunewald-Zuberbier, Zuberbier, Grunewald and Rasche 1972
Use of telemetry to study chewing behavior	Rugh 1971
Discusses underuse of telemetry in clinical and other research	Hanley 1976
Discussion of the behavioral effects of being observed during research, e.g. while telemetry is being used	Moos 1968

Summary of Research Applications continued....

Research Applications	Author(s)
Use of telemetry in studying husband-wife interaction	Soskin & John 1963
Use of telemetry to monitor vocal behavior of adolescents	Purcell & Brady 1966
Use of telemetry to study body movement, e.g. gestures, tics, motor learning	Herron & Ramsden 1967
Use of telemetry and videotapes to study verbal behavior in free play settings	Nordquist 1971
Use of telemetry in evaluating speech and language patterns in preschool children	Gardner 1973

Summary of the Multi-disciplinary Review of Literature

The questions posed by objective number 1 will now be answered:

1. Who uses the instrumentation focused upon by this study?

   The survey indicated that the bulk of research is being done in the areas of medicine, psychiatry, psychology and physiology. Biomechanics and kinesiology are specialized areas in which such instrumentation is being used. Research is being done and/or applications discussed in the areas of counseling, education, instructional technology, and speech and hearing. It must be noted that the areas mentioned are those which turned up in the survey of literature. It is probable that research is being done and/or applications discussed in other areas as well. With regard to telemetry the survey showed its use in speech and hearing, physical education, educational research, medical research and clinical applications.

2. How are researchers using the instrumentation and techniques focused upon by this study? Medical and psychiatric researchers are asking questions primarily of clinical interest. Psychologists are asking questions of clinical interest but, in addition, questions regarding human learning, behavior, perception, etc., which are of considerable interest to researchers in education, communications and other areas. The types of research problems being addressed are detailed in the first section of this chapter and will not, therefore, be listed here.

   Telemetry, as reflected in the survey, has been used for research in speech and language patterns, for the monitoring of freely moving subjects, in physical education research and for monitoring of patients in clinical situations. The survey reflects the fact, stated earlier in the study, that telemetry is underused.

3. What results are being obtained from the use of the instrumentation and techniques focused upon by this study? Some useful results related to voluntary self-regulation of physiological processes, formerly believed to be inaccessible to voluntary control, are claimed in all the areas identified in which instrumentation is being applied. However, because the psychophysiological phenomena with which the instrumentation deals are not fully understood it is necessary to exercise caution in evaluation of research being published. Some researchers warn that poor studies have been done, as well as some, apparently, very sound ones.

With regard to telemetry, the principle results arising from its use are, as reflected in the survey: a) It adds to the unobtrusiveness of research by making it possible to keep most of ones instrumentation at a distance and out of view, b) It allows the research subject to move about freely and in practically any desired environment, c) While it can add a great deal to some kinds of research it may, for other research, add unnecessary complexity, d) None of the research found in social science sources uses telemetry to measure internal physiological activities. Research located was concerned with such things as voice transmission. Such uses fall under heading number 11 in the Instrumentation Taxonomy of chapter 2, that is, non-physiological applications of telemetry.

The preceding paragraphs have summarized the outcomes of the multi-disciplinary survey of literature. After the presentation in Chapter 4 of the results of the survey of education, communication and educational psychology, a coding chart is presented which will categorize the outcomes of the two surveys. That categorization will systematically display areas in which research and applications were and were not found.

Chapter IV

THE LITERATURE REVIEW FOR THREE SELECTED DISCIPLINES AND A SUMMARY OF RESEARCH APPLICATIONS IDENTIFIED IN THIS STUDY

This chapter will accomplish the fourth, fifth and sixth objectives of this study.

For the fourth objective it will describe the results of a survey of journals in the fields of education, educational psychology, and communication. Five journals were reviewed for each field, covering the years of 1970 through 1976. Some of the journals are of interest to researchers in more than one field. For example, AV Communication Review is of interest to researchers in both education and communication. For this search it was listed under journals searched for the field of education. Another journal, Perceptual And Motor Skills, contains a great deal of research which is of interest to educators and was listed as a journal searched for that field even though it might have been listed for the field of educational psychology. The citations from the journals searched were those which dealt with research and applications involving use of the instruments and techniques focused upon by this study. In the psychological journals only those citations were taken which involved research judged to be of practical interest in the fields of education, educational psychology and communication. That is, those types of research were taken which might lead to testing and application of the principles involved in educational or communication settings, e.g. approaches to evaluation of responses or of performance.

For the fifth objective a coding system was introduced which will be used to classify the types of research identified by the study, to identify and display some areas of instrumentation application for which available research was not found in the surveys, and to allow coding of the bibliography of this study to assist in identifying the content of the citations listed.

For the sixth objective this chapter will report the results of interviews and of a discussion group which was arranged with researchers in educational psychology, education and communication. The purpose of the interviews and discussion was to identify instrumentation applications which this study had overlooked or which, to the knowledge of the persons interviewed, had not been done.

Survey of Journals in Educational Psychology (and Psychology)

1. The first journal searched was American Psychologist, journal of the American Psychological Association. With the exception of one special instrumentation issue and two research articles this journal did not provide the type of brief research report, suggestive of cross-disciplinary instrumentation applications, that were being sought.

One research article located, authored by Kimmel (1974), provides and excellent discussion of instrumental conditioning of autonomic responses. He points out that as of the time of writing of the article about 95 experiments had been published dealing with instrumental autonomic conditioning in humans "with over 90% reporting positive results (1974)."

Kimmel points out that data available are subject to differing interpretations and that, hopefully, a theoretical structure to adequately explain the results achieved to date will emerge.

> ....a great deal of additional data has been collected, in both the basic research and applied areas, but only the most preliminary theoretical conjectures have emerged. My own view is that the traditional categories of conditioning must be reexamined and new categorizations developed and evaluated. Perhaps another few years may be all we need; perhaps we will need more than a few years. In either case, the rapidly growing interest and experimentation in the field of instrumental autonomic conditioning, from the not-so-distant past, when it was "not so much imaginary as impossible," to the present, when biofeedback machines for home use are being recommended, must go down as a most remarkable scientific about-face (1974).

Mckinney (1976), in an article in the same journal, provides some insight as to why the location of materials for this study has not been easy. Much of the research done using the instruments focused upon by this study is conducted by the physiological psychologist. McKinney provides a brief history of publication patterns in that field.

> For physiological psychology, there was negligible citation of papers in 1927, but there has been a sizable increase since then. It is, however, not among the more popular fields of psychology as judged by number of journal publications. However, in the November 1975 issue of Contemporary Psychology, 10 books in the area of physiological psychology were reviewed, and 5 were reviewed in the December issue. Psychopharmacology is 12th, but Physiological and Comparative is 24th in rank among the 33 divisions in the 1975 APA directory (1976).

The above citation may be of considerable value in explaining the course that has been followed in research in the fields of educational psychology, general education (e.g. in assessing the physiological and psychological effects of communication) and other fields. McKinney asks the question this way.

> Is the low output in physiological psychology due to psychologists' preoccupation with environmental variables at the expense of organic variables? Will we see a movement toward a greater balance of influence? Are the psychologists who regard the organism as a host to the environment, with a tendency to favor certain stimulating situations over others, increasing? Are not organisms dominated at times by bodily processes and at other times by the environment? (1976)

The special instrumentation issue of American Psychologist was published in March, 1975 (Volume 30, Number 3). Reprints of the issue are available and are, from the point of view of this study, highly recommended. The articles in the instrumentation issue survey a variety of instrumentation areas and attempt to describe the state of the art in each area. Some subjects dealt with are: Instrumentation and Computer technology (with articles on a variety of areas of computer technology and use, e.g. minicomputers, real-time computing, computer language for the psychologist and computer graphics in research): Biopsychology instrumentation and techniques (e.g. NASA contributions to biomedical telemetry; blood pressure and cardiovascular considerations): Sensory information systems (e.g. eye movement recording, human performance study): Clinical and applied research techniques (e.g. biofeedback techniques, electro-anesthesia, instrumentation and sexual responding, radio telemetry applications). This study will not attempt to review the contents of all of the above but, rather, strongly recommend reference to that source. In terms of this study's search for instrumentation applications that issue of American Psychologist corroborates applications reported in this study and, in addition, opens for consideration areas of instrumentation application and development barely touched upon here.

2. The second journal searched was the Journal Of Applied Psychology, published by the American Psychological Association. This journal, did not provide the type of brief research reports that were being sought for this study. Nor did it provide articles concerned, primarily, with the types of instrumentation focused upon by this study.

3. The third journal searched was the Journal of Educational Psychology, published by the American Psychological Association (the 1971 and 1972 issues were missing and could not be reviewed). As with the previous journal this one did not provide the types of report desired. One citation, however, was taken which deals with morning-to-afternoon changes in cognitive performances and the reflection of those changes in the electroencephalogram, (Mackenberg, Broverman, Vogel and Klaiber(1974)). Based on the research described in this citation they state:

> It is interesting to speculate on the pedagogical implications of these results, at least for males. For instance, teaching procedures that seem to involve automatized behaviors, for example, drills oriented toward skill acquisition via sustained repetitive practice, might best be conducted in the morning. Similarly, such content areas as speed and accuracy of reading, spelling and simple additions and subtractions, which have been found to be related to automatization ability...might be most effectively taught in the morning.
>
> On the other hand, subjects that seem to require cognitive-restructuring behavior might best be taught in the afternoon. Proficiency in abstract thinking, mathematics, and in technical science courses, which have been related to perceptual-restructuring ability...might be such subjects. However, much more work is needed to determine precisely which classroom subjects and behaviors correlate with, or involve, automatization and perceptual-restructuring abilities. Unfortunately, the present study cannot be generalized to females. Again, more work is needed.

The above citation summarizes basic research which, due to its complexity, is not likely to be reproduced by most researchers in education, communication, or educational psychology. However, the citation was taken because the instrumentation and techniques treated in this thesis might be used to test some of the experimental conclusions of that research in working educational or communication environments.

4. The fourth journal searched was The Journal Of Psychology, published by The Journal Press. This journal provided one useful citation, describing research utilizing galvanic skin response measurements. As emphasized earlier, citations have been defined as useful for this study if they describe research which depends primarily upon the use of the five categories of instrumentation focused upon by the study, and if the research described seems to have some practical applicability or testability in education or communication. The Journal of Psychology contained several articles involving GSR use but only one was considered useable according to the above norms.

In the research article selected Peretti (1975) describes use of GSR equipment in researching the effects of music upon anxiety, differences in the responses to music of males and females, and differences in the responses of music majors and nonmusic majors. He reports that his research resulted in findings that: music majors, male or female, showed a greater decrease in anxiety than non-music majors; females showed a greater reduction in anxiety whether music majors or not. Peretti states: "These results suggest that being female had a greater effect on performance than being a music major (1975)."

5. The fifth journal searched, one providing an abundance of useful citations, was Psychophysiology, published by The Society For Psychophysiological Research. A variety of research reports are available in this source which describe applications of the instrumentation and techniques of interest to this study. In addition, research is described using a

variety of other types of instrumentation which have potential applications in education and communication, e.g. instruments for measuring heart rate, skin temperature, respiration, etc..

Epstein, Boudreau and Kling (1975) report research in which measurement of skin conductance and heart rate were monitored while subjects were engaged in different levels of motor activity and while they were being exposed to various stimuli. This study makes some interesting comparisons between heart rate measurements and skin conductance measurements. Those comparisons might aid a researcher in deciding which forms of instrumentation to use in research involving motor activity and the input of various stimuli to research subjects.

Klorman, Wiesenfeld and Austin (1975) describe research in which subjects were shown slides of three categories of affective content: neutral, incongruous and depictive of mutilated humans. Measures of skin conductance, heart rate and respiration were taken to determine reactions to viewing of the slides. This research exemplifies a typical application of the instruments and provides a good example of the research methodology and analysis of results appropriate for such research.

Hare, Wood, Britain and Shadman (1971) used slides of homidice scenes, nude females and ordinary objects while measuring skin resistance, respiration, heart rate. They found that these stimuli produced an increase in skin conductance, cardiac deceleration, etc.. Studies such as this provide a model for research into the effects of either the media used (the content and quality of the slides themselves) or the responses of subjects to such media presentations. This brief summary does not attempt to elaborate the details of the research done or the specific physiological findings gotten.

A particularly interesting piece of research done by Barland and Raskin (1975) describes efforts made to evaluate the accuracy of field techniques used in the detection of deception. Typical 'field model' polygraphs measure skin resistance, respiration and cardiovascular activity. 'Guilty' and 'innocent' subjects were interviewed with the authors concluding: "It is apparent that in this experiment the polygraph technique discriminated between 'guilty' and 'innocent' subjects at levels well beyond chance." Research such as this deals with the physiologically measurable aspects of a type of communication behavior, deception. Communication researchers might find such research useful in identifying pertinent physiological measures and in identifying fresh approaches to the study of communication behaviors involved in 'deceptive' communication; e.g. message construction, verbal and non-verbal communication behaviors displayed, group dynamics which might be involved.

Bower and Tate (1976) describe research in retarded and nonretarded youth studying the relationship between reaction time and heart rate. Skin conductance and pulse amplitude measures were taken, also. The authors state that "this study presents a consistent picture of retarded subjects as debilitated in comparison to their (chronological age) peers both physiologically and behaviorally during a (reaction time) task (1976)." This type of research, although involving a variety of instrumentation types not dealt within this study still is of interest to educators.

Some research reports available in <u>Psychophysiology</u> are concerned with Alpha wave production. Brolund and Schallow (1976) report research in which subjects were given reinforcement beyond just hearing auditory feedback of their alpha sounds. Some subjects were offered a choice of monetary reward or extra experimental credit. Others received false feedback. Subjects receiving feedback plus monetary, or other reward, were "clearly more effective in enhancing alpha than any other treatment condition (1976)." Such use of rewards or other backup reinforcement by researchers applying alpha, e.g. for relaxation training, provides an additional testable variable in social science research.

In addition to the types of research described so far, issues of Psychophysiology since 1970 describe a variety of other kinds of research relevant to this study. Alexander (1975) describes research in which assumptions relating to the use of electromyographic biofeedback as a general relaxation technique are tested. Alexander, French and Goodman (1975) report research in which they compare auditory and visual feedback in biofeedback assisted muscular relaxation training. Haynes, Moseley and McGowan (1975) report research into relaxation training and use of biofeedback, from muscle voltage measurements, in the reduction of tension in the forehead (frontalis) muscle). They found that use of biofeedback is significantly more effective than simple verbal instructions, and several other techniques, in achieving relaxation of the forehead muscle.

Herron and Ramsden (1967) report use of a simple telemetry transmitter placed into the heel of a shoe for measurement at a distance of human locomotor activity. Erwin (1971) reports research using telemetry to study changes in cardiac rate during cigarette smoking.

Several other types of research are reported in Psychophysiology which involve instrumentation not among those focused upon by this study. Pupillometry, photographic recording of changes in size of the pupil of the eye, appears to be gaining in interest as a measure of arousal and affective response. Stelmack and Mandelzys (1975), for example, report research relating pupillary response to extraversion and to the response of subjects to affective and taboo words. Tryon (1975) lists a variety of factors believed to influence pupillary response and the sources of research into each of those factors: e.g. research cited states that alertness suggestions decrease and relaxation suggestions increase pupil size; alcohol dilates the pupil; sexually stimulating material dilates the pupil; pleasant tastes cause dilation; solving difficult problems causes increasing dilation. All these are worthy of pursuit and are mentioned because of their relevance to educational, communication, etc., research but the instrumentation for such research is not to be dealt with in this study.

In summary, Psychophysiology provides numerous examples of instrumented research using all the instruments focused upon by this study (Muscle voltage, brain voltage and skin conductance measurement, and use of biofeedback and telemetry techniques). In addition, it includes examples of research designs which might be useful in followup of such research in educational and communication settings. Also, research involving instrumentation using instruments other than the types picked for emphasis in this study is described.

Survey of Journals in Education

1. The first journal searched for the field of Education was American Educational Research Journal, published by the American Educational Research Association. In the issues reviewed (1970 through 1976; 1973 issues were not available) one article was found which was, primarily, a report of instrumented research. That article, in the Spring 1972 issue,

was concerned with photographic recording of eye movements during reading. Since it did not deal with the types of instrument focused upon by this study it will not be elaborated upon.

2. The second journal searched was AV Communication Review, published by the Department of Audiovisual Instruction, Inc., of the Association for Educational Communications and Technology. No articles were found which consisted, primarily, of a report of research using the instruments and techniques focused upon by this study. Some research abstracts dealing with use of capillary blood pressure measurement as an indicator of affect were cited in Volume 18, No. 3, Fall 1970 issue, pages 351-352. An article dealing with analysis of eye-movement recordings which were taken from samples of underachieving secondary and primary students, Brickner (1970), was the only one found in the survey concerned, primarily, with instrumented research.

3. The third journal searched was Educational Technology. This publication provided an article by Knirk and Spindell (1975). They discuss possible applications of electroencephalographic measurements (which include alpha waves), electrocardiograph (EKG), skin conductance (GSR), heart rate, blood pressure, voice analyzers and blood analysis. They state that "These measures can provide useful data for the educator concerned with designing learning environments and associated instructional materials." They state that such measures can reduce observer error in the making of "behavioral observations (1975)." This article was a general discussion of instrumentation rather than a report of research findings of their own.

4. The fourth journal searched was the Journal of Educational Research, published by Heldref Publications, Washington, D.C. This journal did not provide any citations concerned, primarily, with the reporting of instrumented research of the type needed for this study.

5. The fifth journal searched, Perceptual And Motor Skills, might have been listed under journals searched for educational psychology. But, since it includes such a wide variety of research reports useful to researchers in the field of education, it has been listed here instead.

Grynol and Jamieson (1975) report on their research using alpha feedback. They emphasize the need for caution in evaluating the effects of alpha conditioning. Their research indicated the desirability of using a placebo control group in such research. This is needed so that claims will not be made for benefits from alpha conditioning when environmental factors or psychological factors within subjects are responsible for post-treatment results observed. Other studies relating to alpha feedback can be found in Perceptual And Motor Skills.

A number of research reports relating to use of skin conductance (galvanic skin response) measurement were found in this journal. Thompson and Dixon (1974), for example, used GSR to demonstrate that stimulus pictures, pornographic pictures in this case, produced graded physiological responses in subjects.

They summarize this research as follows:

> Functional relationship between emotional reactions as measured by GSR and perceptual response was demonstrated. The power function demonstrates that in a carefully controlled situation, where a psychometrically defined normalcy can be ascertained through pretesting, a reliable index of response to a series of photographs illustrating human sexual activity can be demonstrated. The findings substantiate the theoretical position that psychological functions can be shown for psychologically defined modalities...(1974).

Of particular interest to researchers in media and instructional technology is research reported by Jacobs and Hustmyer, Jr. (1974). They studied the effects of four psychological primary colors on GSR, heart rate and respiration rate. They state:

> ....colors were presented for 1 minute each with GSR, heart rate, and respiration being recorded. There was a significant color effect on GSR but not on the other measures. Red was significantly more arousing than blue or yellow and green more than blue.

Bull (1972) reports research concerning the question of whether there is a rhythmic variation in arousal level in humans during the working day and asks whether such variations can be shown to recur daily. Using GSR as the physiological measure he found, on one of his statistical measures, significantly predictable daily variability in skin conductance activity. Such a predictability in skin conductance response or level of arousal is significant for research in education or communication. Bull states that "..it does seem worthwhile to control for possible time-of-day effects (1972)."

Stern (1973) describe research with GSR which showed that subjects who tend to react to stress with sweaty palms tend to be able to produce greater changes in skin conductance under test conditions and with practice learn to control skin conductance changes better than non-sweaters. What research questions this might raise concerning research in education and communication remains to be seen.

Bronzaft and Stuart (1971) report use of skin conductance measurement (GSR) in studying test anxiety and academic achievement. Students were given a self-report measure of test-anxiety and then their GSR's recorded while taking an examination.

Kaiser and Roessler (1970) report the use of skin conductance (GSR) measurement with subjects viewing stressful motion picture films. The subjects were given the Zuckerman Multiple Affect Adjective Check List (MAACL) both before and after seeing the stressful and bland films. Kaiser and Roessler report that:

> The greatest number and amplitude of GSR's were produced during the stress film and the least during the bland film. A direct relationship between the number and amplitude of GSR's and MAACL scores was obtained. In addition, these GSR indexes paralleled variations in the content of the stressor film. These results support the interpretation that cognitive factors are important in understanding mechanisms of psychological stress (1970).

This type of research is of interest to researchers in education and communication.

Garrity (1975) describes research using EMG measurement in which he measures muscle activity associated with subvocalization. He describes how his measurements were taken and makes recommendations about how the data taken in that type of measurement might best be used.

Carroll (1971) describes research in which EMG measurements were taken from muscles as subjects were exposed to affective visual stimuli. Paben and Rosentswieg (1971) used EMG measurement, and audio and visual feedback, in training subjects to produce specific amounts of muscular tension in the flexor and extensor muscles of the wrist and forearm. Subjects who learned to produce tension at several specified levels upon demand performed significantly better on an experimental motor task.

> Fifteen college women were taught to relax and how to produce, on command, given percentages of maximum tension through EMG. A comparison was made with 15 control subjects of the ability to learn a novel gross motor skill. Significant differences were found, indicating that learned control of general muscular tension facilitates learning..... It may be concluded that a program of neuromuscular tension control facilitates motor learning in the novel

> gross motor skill of paddle-ball hitting. The advantages gained when a complex novel skill is learned relatively quickly are believed to lead a favorable achievement in that skill and therefore could be a very important consideration for educational programs (1971).

Two final studies, both using feedback, but not using the instrumentation focused upon by this study will be described.

Nideffer and Deckner (1970) did research with normal and learning-disabled children in which they compared the ability of the two groups to learn control of fingertip temperature. The outcome of that research suggests further research questions for educators.

> Most experience with learning-disabled children and most theories about their failure to learn despite adequate intelligence levels suggest that such children might learn psychophysiological self-control via biofeedback techniques not at all or much less well than educationally normal children.....That learning-disabled children did not prove more difficult to condition than normals in this study is a rather astounding finding. This may be an accident of this particular population rather than a law of learning for learning-disabled children, but the results of the study suggest that when an experimental situation reduces irrelevant stimuli, and reinforcement is consistent and immediate, learning-disabled children may learn at least as well as normals (1970).

Nideffer and Deckner (1970) describe an experiment in which an athlete was given verbal instructions concerning relaxation exercises he was to perform periodically. Performance of the athlete improved within a short period of time. The authors do not claim that the relaxation procedures, alone, produced the improvement. However, they raise the question of the effect of tension level on athletic performance and the different effect of tension level on short term athletic performance (e.g. shot-put) or long term performance (e.g. running). Also, they state that:

> .....performance may be impaired when an athlete practices at one (relatively low) level of tension and performs in competition at a different (probably considerably higher) level of tension (1970).

Perceptual and Motor Skills contains a variety of other research reports of interest in education, educational psychology and communication. It should be a valuable resource for researchers.

Survey Of Journals In Communication

1. The first journal searched for this area was Communication Research, an international quarterly. Issues from 1974 and 1976 were reviewed, the 1975 issues missing. The type of instrumented research report needed for this study were not found there.

2. The second journal searched was Human Communication Research. It, also, did not provide reports of instrumented research.

3. The third journal was the Journal Of Communication. A very useful article by Crane, Dieker and Brown (1970) discusses physiological responses to the communication modes of reading, listening, writing, speaking and evaluating. They describe research in which skin conductance (GSR) and heart rate measurements were taken. Bostrom (1970) studied affective, cognitive and behavioral dimensions of communicative attitudes. Although this is not a report of instrumented research the author does discuss, among other things, the reflection of affective response in skin conductivity and rate of heartbeat.

Donohew, Parker and McDermott (1972) report use of physiological measurement in the study of information selection. They measured skin conductance (GSR)and monitored eye movement photographically. The GSR was used to measure arousal of subjects during exposure to various types of stimulus materials. They cite other studies of communication factors which included use of physiological instrumentation, specifically GSR.

Klemmer and Snyder (1972) describe use of non-physiological instrumentation in research measuring the time spent communicating. A watch alarm, which rang at random times, served as a cue to subjects to record their activity each time the alarm sounded.

Harrison and Knapp (1972) in an article discussing nonverbal communication systems describe efforts of researchers to catalog research factors in that area. They present, as an example, a listing of 18 nonverbal research areas, one of the areas listed being the area of physiological activity.

Watson (1972) discusses research needs and directions in the area of proxemic research, study of the relationship between humans and space. This area is concerned with how humans structure, use and function within space. A number of research factors in that area relating to physiological responses, effects of the physical environment, etc., are amenable to the use of instrumentation techniques, including the types focused upon by this study.

4. The fourth journal searched for communication was The Quarterly Journal Of Speech, published by the Speech Communication Association. This journal contained a great deal of material concerning communication research, rhetorical and literary criticism, broadcasting, etc.. Only one article was found that dealt specifically with instrumented research. Fletcher (1973) discusses "Old Time GSR And A New Approach To The Analysis Of Public Communication (1973)." He discusses application of skin conductance measurement, and other physiological measures, in assessment of speech communication, message construction for commercial purposes, etc.. He states that:

> .....in the case of instructional media the high cost of producing films and videotapes make pre-testing an economically justifiable possibility. Using a composite record of audience physiological response a producer could engineer the attention-values of the material--removing uninteresting sections, heightening attention values in portions where retention of content is particularly important to instructional objectives (1973).

Fletcher describes means by which some students in a classroom setting might be monitored for skin conductance and their responses processed real-time by a computer. Adjustment of instructional strategies might be accomplished on the basis of student responses. Fletcher includes in his article discussion of a variety of potential applications for instrumentation which have not been cited here. He predicts that use of physiological instrumentation will increase in the foreseeable future.

5. The fifth journal searched for communication was Sociometry, published by the American Sociological Association. This journal deals with a variety of research areas of interest in the fields of education, educational psychology and communication, but no citations were found which were concerned, primarily, with instrumented research.

Summary Of The Literature Surveys And Completion Of Objective Number Five

The questions posed by Objective No. 4 will now be addressed, based on the results of the literature review for education, educational psychology and communication.

Based upon this selective literature review, who uses the types of instrumentation and techniques focused upon by this study? The selective review confirms the findings of Chapter 3. Most of the research being done with instrumentation of the types of interest to this study is being done by researchers in physiological psychology, general psychology and medicine. A problem faced during the survey was the inadequate identification of the professional background of authors. In some cases they were identified, e.g. as psychologist, but usually no biography was given. Thus, it had to be presumed that authors cited from the psychological journals were probably psychologists. In the communication and educational journals most of the citations taken provided little help in identifying the background of the authors.

For the fields of education and communication it can be said, at any rate, that a few articles have appeared, authored by communication, tele-communication, speech, and educational researchers. The bulk of research, however, is being done by psychologists, psychiatrists and medical clinicians researching clinical problems.

How are researchers using the instrumentation and techniques focused upon by this study? They are being used in research concerning cognitive performance (as reflected in EEG measurements), effects of music upon anxiety, sutdy of motor performance, study of affective responses to visual stimuli, the study of proxemics, performance of normal and learning-disabled children, study of the effects of reward upon performance, study of relaxation techniques, study of capillary blood pressure and its relation to affective response. Citations found in communication sources consisted mostly of discussion of the feasibility of instrumentation use in communication research. Some, however, reported actual research, e.g. in study of audience or individual response to presentations.

What results are being obtained from the above research? Most of the research found in this selective literature review was done by psychologists, psychiatrists and medical clinicians and was found in literature related to those fields. The principal result of those studies, for the purposes of this survey, is that they point the way for followup research in education and communication. The survey indicates, for example, that skin conductance measurement is, probably, the most common technique used in studies involving human response to affective stimuli. In some studies it is used as the principal data source, while in others it is used in conjunction with other measures such as tests and questionnaires. The use of GSR, therefore, with competent psychological and physiological advice, suggests itself as a potential starting point for an educational or communication researcher who wishes to apply some of the research results described in this study to problems in those areas.

Muscle voltage measurements also seem applicable to research into a variety of educational and communication problems.

A Listing of Research Applications Identified in the Search Done for This Chapter

The research described in this chapter will now be displayed in chart form. As in chapter 3 it will be listed in order of occurrence in the chapter. This chart, and the summary chart of chapter 3, provide the basis for the coding chart which follows in this chapter which identifies applications of various types of instrumentation.

Table 5

A Listing Of Research Applications Of Instrumentation Identified In The Education/Educational-Psychology/Communications Literature Search

(Listed in order of occurrence in chapter)

Research Applications	Author(s)
discussion of computer technology as applicable to the field of psychology, of various types of physiological instrumentation, of biofeedback techniques, etc.. Many areas not listed here are touched upon	American Psychologist special issue, March 1975
discussion of the high degree of success in conditioning of autonomic responses with biofeedback instrumentation	Kimmel 1974
AM to PM changes in cognitive performance as reflected by changes in brain voltages	Mackenber, Broverman, Vogel & Klaiber 1974
use of GSR to measure effects of music upon subjects	Peretti 1975
study of motor activity using GSR and heart rate measurements	Epstein, Boudreau, Kling 1975
study of subject response to slide presentations using GSR, heart rate and respiration measures	Klorman, Wiesenfeld, Austin 1975
study of subject response to slide presentations using GSR, heart rate and respiration measures	Hare, Wood, Britain & Shadman 1971
physiological measures used in detecting deception	Barland & Raskin 1975
reaction time as a function of heart rate GSR and pulse amplitude, measured in retarded and non-retarded children	Bower & Tate 1976
use of rewards & other reinforcements in encouraging increased production of alpha waves in subjects	Brolund & Schallow 1976

Summary of Research Applications....continued

Research Applications	Author(s)
EMG as a relaxation technique	Alexander 1975
muscle relaxation training using EMG with comparison of audio and visual feedback	Alexander, French & Goodman 1975
muscle relaxation using EMG, comparing value of different types of feedback	Haynes, Mosely & McGowan 1975
use of telemetry to measure walking activity	Herron & Ramsden 1967
use of telemetry to study effects of cigarette smoking on heart rate	Erwin 1971
measurement of eye pupil size as a guage of affective response	Stelmack & Mandelzys 1975
measuremeny of eye pupil size as a guage of affective response	Tyron 1975
application of a variety of physiolog- ical measures in educational research	Knirk & Spindell 1975
use of various research designs in evaluating effects of alpha conditioning	Grynol & Jamieson 1975
use of GSR to measure affective response to picture stimuli	Thompson & Dixon 1974
use of GSR, heart rate and respiration as measures of response to various colors	Jacobs & Hustmyer 1974
use of GSR to measure AM-PM differences in arousal level of subjects (i.e. daily variability)	Bull 1972
ability of persons with sweaty palms to control skin conductance variations better than others	Sterm 1973
study of test anxiety using GSR and written measures	Lehman 1971

Summary of Research Applications....continued

Research Applications	Author(s)
study of response to movies using GSR and written measures	Kaiser & Roessler 1970
use of EMG feedback in reduction of subvocalization	Garrity 1975
use of EMG in measuring affective response to visual stimuli	Carroll 1971
use of EMG in teaching subjects to control level of muscular tension in muscles	Paben & Rosentswieg 1971
comparison of control of fingertip temperature in normal and learning-disabled children	Nideffer & Deckner 1970
effect of verbal relaxation instructions in an athlete	Nideffer & Deckner 1970
physiological responses to reading, listening, writing, speaking and evaluating (using GSR)	Crane, Dieker & Brown 1970
cognitive, affective and behavioral dimensions of communicative attitudes: physiological correlates	Bostrom 1970
physiological measurement in study of information selection	Donohew, Parker & McDermott 1972
measuring time spent communicating	Klemmer & Snyder 1972
cataloguing non-verbal communication factors	Harrison & Knapp 1972
research needs in the area of proxemics	Watson 1972
use of GSR in measuring physiological correlates of public speaking	Fletcher 1973

A Coding Chart For Classification Of Types Of Instrumented Research

This section will accomplish the fifth objective of the study, development of a coding system for classification and identification of types of instrumented research found, and not found, for this study and, also, for coding of the contents of citations in the bibliography.

In Chapter 2, taxonomies of instrumentation and research factors were developed. Two purposes for their development were: to develop a picture of available instrumentation versus a wide range of research problems: to show where the instruments focused upon by this study fit in the range of available instrumentation. As mentioned in Chapter 2 a variation of the instrumentation matrix format will be used now as the basic format for a coding system. The coding system will display the instrumentation types focused upon by this study opposite the types of research application which were identified in the surveys done for Chapters 2 and 3. Potential research applications for which no citations were found in the searches will be represented by empty cells in the coding matrix.

Thus the matrix serves as: a) a guide to current applications, b) a guide to areas in which new applications might profitably be undertaken and, c) as a coding guide for bibliography citations.

TABLE 6

Coding Chart For Classification Of Instrumented Research

Some of the numbers appearing on chart refer to citations in which instrumented research is discussed but was not carried out. Others are reports of actual research. Empty squares represent areas of application not found in the surveys done for this study.	Instrumentation & Techniques For Data Gathering, Storing, Processing, Display	1.Electroencephalography(EEG) brain voltage measurement e.g. delta,theta,alpha,beta	2.Electromyography (EMG): muscle voltage measurement	3.Galvanic skin response(GSR) skin conductance measurement	4.Feedback techniques:visual, auditory,physiological,smell, taste,tactile,etc.	5.Telemetry techniques:trans-mission of data by radio,wire, light,sound,infra-red, induction,etc.	6.Coding for sources which discuss a variety of instru-mentation types (beyond categories 1 to 5)
A. <u>Communications Research Problems</u>							
1. deception				1.3			
2. group dynamics							
3. response to violence in media, etc.				3.3			
4. message construction				4.3			
5. response to speaking, listening, evaluating, writing				5.3	5.4		5.6
6. proxemics							6.6
7. public speaking and physical measures				7.3	7.4		7.6
8. affective response, e.g. to taboo words, stimuli				8.3			
9. time spent communicating							9.6
10. verbal/non-verbal communication & behaviors				10.3	10.4		10.6
11. voice analysis							
B. <u>Educational and Ed. Psych. Research Problems</u>							
12. arousal (psychol. & physiol.) & learning, forgetting		12.1	12.2	12.3	12.4	12.5	12.6
13. attention, orienting response				13.3			
14. behavioral control: conditioning of autonomic functions, self-control & regulation		14.1	14.2	14.3	14.4		14.6
15. cognitive styles		15.1		15.3			15.6
16. counseling and instrumentation		16.1	16.2	16.3	16.4		16.6
17. dehumanization and technology		17.1	17.2	17.3	17.4		17.6
18. drugs: use in counseling and educatioo							18.6
19. hyperkinetic children		19.1			19.4		

TABLE 6

continued...

Some of the numbers appearing on chart refer to citations in which instrumented research is discussed but was not carried out. Others are reports of actual research.

Empty squares represent areas of application not found in the surveys done for this study.

Instrumentation & Techniques For Data Gathering, Storing, Processing, Display	1.Electroencephalography(EEG) brain voltage measurement e.g. delta,theta,alpha,beta	2.Electromyography (EMG): muscle voltage measurement	3.Galvanic skin response(GSR) skin conductance measurement	4.Feedback techniques:visual, auditory,physiological,smell, taste,tactile,etc.	5.Telemetry techniques:transmission of data by radio,wire, light,sound,infra-red, induction,etc.	6.Coding for sources which discuss a variety of instrumentation types (beyond categories 1 to 5)
20. Instructional technology and media (visual, audial, tactile, etc.)	20.1	20.2	20.3	20.4		20.6
21. Intelligence	21.1		21.3	21.4		21.6
22. Interaction: student-teacher			22.3			22.6
23. learning: e.g. verbal instruction vs. biofeedback	23.1	23.2	23.3	23.4		23.6
24. learning- disabled, retarded, maladjusted children			24.3	24.4	24.5	
25. linguistics: verbal pattern study, etc.					25.5	
26. motor activity & performance	26.1	26.2	26.3	26.4	26.5	26.6
27. oculomotor activity: eye movement, blink rate, pupillometry & affective response	27.1	27.2	27.3	27.4	27.5	27.6
28. perspiration e.g. rate, palm sweating, palmar prints			28.3	28.4		
29. programmed instruction, individualized instruction						
30. reaction time: e.g. vs age	30.1		30.3	30.4		
31. reinforcement, rewards, motivation, incentives	31.1	31.2	31.3	31.4		31.6
32. relaxation: muscular, systematic	32.2	32.2	32.3	32.4		32.6
33. sex differences, e.g. in teachers & researchers (effects of); in anxiety reduction thru music etc.			33.3			
34. stress, tension, fatigue	34.1	34.2	34.3	34.4		34.6
35. subvocalization		35.2		35.4		
36. teaching, training strategies, revision of	36.1	36.2	36.3	36.4	36.5	36.6
37. test anxiety	37.1	37.2	37.3	37.4		37.6
38. unobtrusiveness of research	38.1	38.2	38.3	38.4	38.5	38.6
39. violence, response to viewing of			39.3			
C. Kinesiology, kinesics						
40. bodily movement, muscle activity, e.g. athletic		40.2			40.5	

D. A variety of instrumentation applications of medical, psychiatric or physiological interest were identified by the searches. Since they are not of immediate interest in the fields of education, communication and educational psychology they will only be listed, rather than charted. They are: blood pressure, bronchial asthma, cardiac arrythmia, chewing behavior, heart rate, blood flow, hypertension, migraine and tension headaches, sexual function and extinguishing of phobias.

Using the Coding Chart as a Guide for the Generation of New Research and Instrumentation Applications

The Coding Chart for Classification of Instrumented Research shows some empty cells. Some of those cells are empty, undoubtedly, because of limitations in the literature searches done for this study. Applications of the types of instrumentation listed may have been done, or may be in progress, in studying the research factors for which empty cells are shown. However, conversation with researchers, e.g. in the field of communication, indicates that some of the 'empty cell' activities, if pursued, will be truly innovative.

An example will now be given of how the empty cells in the chart might lead to innovative instrumentation applications.

As an example the empty cell at the intersection of 'group dynamics' and 'galvanic skin response' will be considered. A teacher or researcher in the field of communication has, it will be hypothesized, read this study and decided to set up the following classroom situation:

1. Instrumentation and research problem of interest: The teacher wishes to use galvanic skin response measurement as a supplemental source of input during a class on group dynamics.
2. Procedure: During a class session devoted to the study of the dynamics of group discussion a group discussion will be conducted. The arousal level of four discussion group members will be monitored and visually and audially displayed to observers of the group discussion. For example, in a class with 30 members, four will be in the discussion group and twenty-six will be observers.

3. <u>Strategy</u>: 1) The teacher will lead the discussion and at selected times will introduce taboo or offensive language into the conversation. 2) Change in arousal, as reflected in galvanic skin response changes in the four participants, will be observed, recorded (on tape and by a chart recorder), and used afterward as the basis for debriefing of the group members and as the basis for a class discussion.

Some questions which might be appropriate for the group debriefing and class discussion might be:

a. Did the group participants react physiologically to the language interjected by the teacher?

b. How did they react?

c. To what words did they react most?

d. Did certain members of the group show stronger reactions than others?

e. <u>IF</u> group members were allowed feedback of their GSR during the discussion did this have any effect on their subsequent behavior? What effect? <u>Why</u> might their subsequent behavior have been influenced?

f. Is it possible to say that the use of such language by a group member might be said to have any important effects on the dynamics of the group discussion? For example, did it change the behavior or attitudes of group members toward the person using the language? Could the use of such language be useful as a <u>strategy</u> in certain group situations?

4. <u>Variations</u>: Depending upon circumstances the user of the above format could introduce several variations. For example, group participants may or may not be allowed audible or visual feedback of their arousal level during the discussion. If it was not allowed they could be questioned about how they perceived their reaction to the stimulus words before being shown chart recordings

of how their GSR arousal level actually varied. A more substantive variation would be to use the 'group discussion with GSR measurement' format with variables other than taboo or offensive language. It may be desired to introduce 'deception' (another 'empty cell' variable from the Coding Chart) into the group discussion. The goal might be to observe the arousal level of group participants when the deception begins to be suspected by group members. Or, it may be of interest to focus on the arousal level and demeanor of the person selected to introduce deception into a discussion (e.g. while lying about something of interest to the group participants). Barland and Raskin (1975) provide interesting background for those who might wish to pursue the topic of deception.

Using examples such as the above it would be possible to assemble a workbook of innovative projects relating to an area of interest, e.g. group dynamics. Allowing a bit of reign to the imagination such a workbook might be entitled "Projects in Group Inner-Dynamics."

The Coding Chart assimilates information from the computer and manual searches conducted for this study. The next section describes the effort to add to what was learned from those searches, to get input from active researchers in the fields of education, communication, and educational psychology.

Arranging Of Interviews and a Formal Discussion With Researchers in Education, Educational Psychology and Communication

This section deals with objective number 6 of the study. After the data of chapters 3 and 4 was compiled an effort was made to add to that data by seeking input from researchers in the fields of education, educational psychology and communication (Dr. Joseph Byers, Dr. Robert Davis and Nicholas Stoyanoff of Michigan State University). The researchers were contacted and a meeting arranged in which each was provided with the results of the surveys done for this study. Each was given the opportunity, during that meeting, to use EEG alpha-theta, galvanic skin response, and EMG muscle voltage units. Each of the three units provided audible and visual feedback. The purpose of that experience was to supplement the data from the surveys with fresh experience with the instrumentation. After these initial interviews a formal discussion was scheduled in which the three researchers were encouraged to identify instrumentation applications in their fields which may not have been identified by the study. They were encouraged, also, to state their wishes as to what new kinds of instrumentation should be developed to apply to hiterto uninstrumented, or inadequately instrumented, research problems in their field. Finally, their views were sought concerning the types of research problems which were discussed in this study.

Initially, the formal meeting of researchers was to have been a brainstorming session. It appears, however, that the 7 computer searches done for this study identified most of the applications being made of instrumentation in the fields of the participants. Therfore, the meeting became a discussion in which the participants: a) discussed the types of application already identified, b) suggested new applications, c) suggested areas of research for which new instrumentation, beyond what is available, or variations of existing instrumentation, need to be developed, d) discussed means of communicating instrumentation needs of their areas to industry, e) discussed the need for provision of a university structure to provide access to instrumentation, technical assistance and information on potential applications.

Some Questions And Issues Raised In The Discussion

Can physiological measures be used as indicators of aspects of the 'information processing' which occurs in communication or learning situations? The searches done for this study located extensive research dealing with electroencephalographic study of brain functions. The purpose of such research was to isolate and define organic functions, to aid in the diagnosis of disease or malfunction within the brain, etc.. Research is available which deals with the nature of 'information processing' in the brain but literature describing the practical translation of such research into techniques for evaluating communication processes was not found by this study.

Can tactile feedback be utilized in situations where the visual, auditory, etc., senses are 'overloaded'? The capability of current technology for producing tactile stimulators in a variety of forms is great. Demand for development of such technology was not apparent in the literature searches in the fields of education and communication. Some development has occurred in aerospace research. NASA used tactile stimulators to signal astronauts working in environments where a large amount of visual and auditory information was constantly being generated. Some use of tactile methods has been made with systems for communication of information to blind or deaf people.

Can galvanic skin response be applied to detect 'information overload'? Research was not located in which such an effort was made, thought it may exist. If 'information overload' is reflected in changes of a person's general level of physiological arousal GSR would be an applicable measure.

To what extent can GSR be used to plot children's response to TV violence and as an aid to operationally define that response? GSR is being used currently to determine people's response to various TV news commentators. Hiring and firing of commentators is being done based on those public reaction measures. As an indicator of response to violence GSR can be used to observe changes in arousal level but other measures would have to be used to ensure that what is being indicated is truly an emotional response and not a function of the person's orienting response (orienting to or adverting to stimuli in one's environment produces physiological changes). The question of operationally defining a person's response includes the distinguishing of the following. Is there a difference between a person's response to physical versus verbal violence, real versus symbolic or mythical violence. Would there be a difference, for example, between the reaction to violence on a TV police type program and violence in cartoon form?

The variety of other questions raised and observations made in the discussion was so extensive that some of them will be listed without comment:

1. There is a need for better integration technology to provide constant rather than occasional display of processed data during research and during classroom activities. For example, programmable calculators can be programmed to process and display data; e.g. a teacher can get immediate feedback on the performance of students.

2. Heat measuring instruments are more commonly available now. Are their applications for them in education or communications research? Is enough known of the body's heat transfer processes to make possible its use as a 'psychothermal' measure, e.g. less stress less heat?

3. Some problems relevant to education and communications research: location of measures to indicate types and levels of information processing, e.g. visuals versus audio-visuals, or processing of audio information alone; measures of information processing in face to face versus telecommunication situations, e.g. the effects of the absence of smell, touch or sight in wired communications. Can information be adequately defined in terms of 'bits' or other inputs to a person and thus, make quantification of information tolerance or overload levels possible? In such a quantification can psychophysiological instrumentation provide a measure of physical correlates to either, or both, the information input process and the 'overload' process? Is there a measure of energy expenditure in a communication exchange between people? Is there a thermodynamic aspect to an interpersonal exchange, i.e. measurable thermodynamic activity? Can psychophysiological instruments display physiological correlates of propinquity (physical nearness) or the effects of removal of persons in a communication interaction to a distance?

4. Telemetry: its use to provide ongoing information in classroom or communication settings is recognized by many researchers and teachers but it still is little used: The suggestion was made that telemetry at short range could be done with a variety of visible-light or infra-red light circuits that are avilable now. Such transmitters would involve simpler equipment than radio telemetry, lower cost, less problems from interfering signals, and little or no government regulation of the power levels used, to determine communication patterns within certain occupations, e.g. in studying the activities of executives, secretaries, teachers, etc., over long spans of time.

The above listings give an indication of the scope of topics that were covered in the discussion. For a brief, one-time meeting the range of topics covered, of suggestions made, and of questions posed was remarkable. The purpose of the meeting was to identify new instrumentation applications. It accomplished that goal and provided several other profitable outcomes as well. For example, the suggestion was made that a series of such meetings might serve to catalyze interest in the use and development of instrumentation. Further, if an effort is being made to develop an instrumentation resource center type of activity such meetings can serve to educate and gain the interest of researchers and other faculty interested in using instrumentation.

Summary of The Results Of Chapters 3 and 4

Chapter 3 attempted, through its broad survey of literature, to determine who, in general, uses certain types of instrumentation and techniques. This chapter has attempted to search more deeply in three selected areas of study. The purpose of the two searches was to prepare the way for application of those instruments and techniques in the three areas of education, educational psychology and communication.

This chapter has, also, introduced a coding system for classification of instrumented research and provided examples of its use. The chapter concluded with a description of an effort made to add to the variety of instrumentation applications which were identified in the surveys of Chapters 3 and 4. Researchers in education, educational psychology and communication were interviewed and later brought together for a formal discussion in an effort to identify new research applications in those areas.

Chapter 5 will include discussion of an instrumentation resource center type activity and a summary of the results of this study.

Chapter V

SUMMARY AND CONCLUSIONS

The earlier chapters of this study have developed a picture of the types of instrumentation that are available and of the variety of applications that can be made of it. Although that information is essential to the process of diffusion of innovation in instrumentation there remains yet another step to be taken. Some means must be provided through which researchers, teachers, etc., can be provided access to instrumentation. Progress in electronic miniaturization has made possible smaller and less expensive brain wave, muscle voltage, galvanic skin response, and other instruments. But few researchers, clinicians, or teachers are familiar with or have access to such equipment. And, as stated on page 1 of this study, since most have little or no knowledge of the instruments they are not likely to consider such technology as potential contributors to the solution of their problems. To accomplish the seventh objective of this study a means of bridging the technological communication gap described above will be presented. The final part of this chapter will summarize the results of this study.

Development Of An 'Instrumentation Resource Center' Structure

Prior to the conducting of this study, appointments were arranged with researchers and department heads in several Michigan State University departments. The purpose of these meetings was to assess the need for instrumentation within each department. All of those consulted expressed the desire and need to expand research and application within their departments to include use of the instruments focused upon by this study. All expressed the questions, however, of how relevant technology could be identified, selected for purchase and introduced in a meaningful way to persons within their departments.

It is to fill those needs that this study will now propose establishment of a formal structure within institutions of higher education which will function as an 'instrumentation resource center'. The resource center would provide researchers, teachers, etc., in the social sciences and other areas with:

a. advice and assistance in assessing instrumentation needs and in planning applications or research using electronic instrumentation

b. access to studies and data from various areas of application and research (social sciences, etc.) where related use has been made of such instrumentation

c. provide, temporarily, instrumentation and guidance in procedures for operating and applying it

d. refer potential users of instrumentation to appropriate professionals when indicated: e.g. should research involve measurement of muscle voltages in a particular location referral to a physiologist or physiological psychologist would be desirable to ensure that electrode placement is correct and that any problems associated with those measurements be identifiable and anticipated

e. provide information concerning commercial instruments available for purchase (this would include information about equipment specifications, availability of repair facilities in case of breakdown, relative cost of various brands of instruments versus the measurement needs of the user, etc.)

Another important function of an instrumentation resource center would be to conduct research and engage in developmental activities. Since the center would be in contact with faculty, graduate, and undergraduate students, in a variety of areas it would over time confront many unresolved research problems and instrumentation needs in each of those areas. Some of those needs would be resolved by the center. Others problems might be communicated to industry, to appropriate professional organizations, governmental agencies, etc..

The functional structure of an instrumentation resource center would derive from the functions described above, from the range of instrumentation to be included as part of the service, and finally, from the scale of the operation decided upon (e.g. it might be a university-wide service or it might, initially, be housed within one or two departments). At the simplest level one person competent in the theory and application of the instruments provided would be required. That person would need a set of instructional materials, including appropriate print, visual and audio resources, and, perhaps, appropriate models and simulators. In addition it would be necessary to have channels of communication to appropriate resource persons, e.g. a physiological psychologist or physiologist, or persons with other areas of expertise which may be involved in an instrumentation application. In addition, channels of communication to commercial instrumentation sources are needed since application of general types of instrumentation to the special needs of researchers in a particular area immediately generates suggestions about the tailoring of instrumentation for the needs of that area. For example, the author of this study, has communicated with manufacturers about modification of existing equipment to suit the needs of local researchers better: e.g. integrated circuits used in their devices should be plugged into sockets rather than soldered directly to the printed circuit boards so that local researchers can, in case of breakdown during use, quickly replace them. Also, the needs of researchers and non-researchers differ in a particular instrument. The researcher may desire a digital readout of information so that accurate figures can be recorded. But a teacher, for example, may wish to use an instrument to train or condition students to relax and thus may prefer to have a simple meter readout which shows up-and-down trends better than a digital readout. If industry does not provide for both needs then one of those categories of people will be poorly served by the instrument.

The preceding discussion has outlined some of the functions and structural characteristics of an instrumentation resource center. An effort to implement the instrumentation center concept in a university setting will be made by the author of this study.

Summary Of The Results Of This Study

It was stated in chapter 1 that the primary goal of this study was to attempt to innovate through identifying and, then, through recommending to researchers, teachers, clinicians, etc., tools to which they may, previously have had no introduction or access. The identification of the types of instrumentation that are available and of the types of applications that are being, or could be, made of them was accomplished in the two taxonomies of chapter 2. The research factor taxonomy was intended to touch very broadly a wide range of problems. Within individual areas of study a research taxonomy would be more focused and specific, as is the chart in chapter 4 of this study which lists problems from communication, education, and educational psychology opposite the instrumentation focused upon by this study. The instrumentation taxonomy of chapter 2, however, represents a fairly thorough coverage of instrumentation that has been identified as useful for areas such as education or communication. There are a number of other available instruments that might be added to taxonomy. It remains to be determined whether those measures will prove useful in education, etc.. For example, instruments are available which measure the impedance, that is the resistance to the flow of alternating currents, of various areas of the body. Impedance is related to a variety of functions, such as respiration, within the areas measured. Some such measures may be of interest to educators, etc.. At present the devices are used by biomedical researchers and a few clinicians. In summary, however, the instrumentation taxonomy provides a starting point for further study and analysis of instrumentation types and applications. It provides the basis, also, for development of a philosophical overview of instrumentation.

Having provided the above background information this study proceeded to accomplish two things: a) to search any available literature which it was thought might identify current or potential applications of the instruments focused upon by this study (brain wave, muscle voltage, skin conductance and telemetry): b) to search literature within the fields of education, communication and educational psychology to determine current or potential applications of the instruments in those areas. The first search included seven computer searches and resulted in development of a good picture of current usage. The narrower search was equally useful in identifying instrumentation activity in the three disciplines searched.

The coding matrix introduced in Chapter 4 organized the research applications from both searches and provided one of the most useful outcomes of this study. The matrix shows areas where instrumentation useage occurs and identified those areas where the searches found no relevant citations. The empty cells on the matrix suggest potential applications of instrumentation. It is understood, of course, that this study may not have located existing research of the types represented by some of the empty cells.

The interviews and discussion group arranged with subject matter experts proved to be successful in identifying instrumentation applications not found in the literature surveys. The use of such a discussion format, involving researchers from various departments, produced valuable suggestions concerning applications and the specific instrumentation needs of each area.

Next, having identified instrumentation applications within several social science areas a crucial question was addressed: How will interested persons learn about and acquire such instrumentation? A formal structure, an instrumentation resource center activity, was described which could mediate technology to the variety of potential users in a university setting.

Conclusions and Recommendations

The principal conclusion arising from the research done for this study is that there are, indeed, useful applications of psychophysiological instrumentation in the social sciences, and particularly, in education, communication and educational psychology. The two literature surveys yielded not only a report of current applications but of potentially valuable new ones as well.

A second conclusion arises from interviews held with a variety of researchers and department heads at Michigan State University while this study was being completed. These persons are aware of the existence of physiological instrumentation and without exception expressed the desire to gain access to that instrumentation.

Three recommendations will be made, based on the conclusions just stated. First, it is recommended that further surveys be done identifying instrumentation applications in education, educational psychology, communication, and in other social science areas which were not surveyed by this study. As a part of such surveys the use of discussion groups including researchers from diverse backgrounds is suggested as a valuable means of identifying needs within each field.

Second, it is recommended that the taxonomies of instrumentation and of research factors be further developed. In the instrumentation taxonomy, for example, the rationale for categorization of the instruments and the definition of the unique function of each instrument needs to be built upon. A finer discrimination of the nature of the inputs, of the internal processes, and of the outputs of each instrument needs to be made. As for the research factor taxonomy it is suggested that similar taxonomies be constructed for specific areas of interest. Improvement of the instrumentation and research factor taxonomies would make possible construction of a more thorough matrix for a field such as communication or education, identifying existing research and displaying areas where new activity might be initiated.

Third, it is recommended that steps be taken to implement some form of 'instrumentation resource center' activity to test the readiness of teachers, researchers, etc., to attempt use of new technology. This author has, during the course of the study, been approached by a variety of persons, some interested in research, some interested in relaxation techniques or evaluation of instruction, but all quite prepared to accept new technology into their activities. But in nearly all those cases there was no available access to instrumentation.

In conclusion, it is believed, based on the results of this study, that the areas of social science surveyed comprise a ready and fertile ground for efforts to diffuse innovations in instrumentation. And since teachers and researchers in the social sciences are by profession diffusers of knowledge it is especially important that they have access to innovative technology.

APPENDIX A

Sources of Data For This Study

To acquire needed citations the following was done. A bibliography of literature on the use of the specified forms of instrumentation was assembled. It includes information gotten from the following computer searches:

1. COMPENDEX (Computerized Files of Engineering Index, Inc.) search on October 2, 1976. This data base covers the period from January, 1970, to January 1977, including all citations and abstracts found in the monthly issues of Engineering Index. This base provides international coverage of virtually all engineering disciplines through journals, proceedings, government reports and other sources.

   The search keywords, found in Engineering Index Thesaurus, were: bioelectric phenomena, bioelectric potentials, telemetering, biomedical engineering.

   Results: In going through the Engineering Index Thesaurus to find appropriate keywords for this system it became apparent that the system's indexing showed few of the terms that are of interest to this study. The citations available there are concerned, primarily, with engineering, physics and technical developments other than the application of instrumentation to living subjects. In summary, this search provided no citations of use to the study.

2. DATRIX II search on February 13, 1976. This computerized retrieval system (offered by Xerox University Microfilms, Ann Arbor, Mi.) accesses American dissertations (back to 1861) and Canadian dissertations. The search was done for the years 1960 to 1976.

   The search keywords were: biofeedback versus fourteen other keywords (e.g., remote monitoring, telemetry, galvanic skin response, electromyography, alpha waves, theta waves, feedback, behavior modification, monitoring systems).

   Results: The results of this search were very good. It is notable that in the 1970's a number of dissertations have begun to appear which examine the use of biofeedback as a technique, specifically feedback of such things as alpha brain wave voltages and muscle voltages. Such studies are beginning to define the value of the above in the learning process, in the regulation of a variety of physiological and psychological factors.

3. ERIC (Educational Resources Information Center) search on March 22, 1976 and December 7, 1976. ERIC covers reports and periodical literature in education and education-related fields. Its indexes, Current Index to Journals in Education and Research in Education, cover about 1050 publications plus various speeches and presented papers.

   The search keywords included all those done in the previous search plus biorhythms and psychophysiology.

   Results: This search provided about fifteen very good citations and a variety of others which were relevant or of peripheral interest. In summary this system is one in which an ongoing search to provide newer citations in the areas of interest will be worthwhile.

4. MEDLINE (Medical Literature Analysis and Retrieval System-on-Line) and MEDLARS II (which is the off-line search performed on MEDLINE). These searches were done on March 5, 1973 and February 11, 1976. They provide comprehensive journal coverage of the world's biomedical literature. One of the indexes for the system is Index Medicus. The search keywords were similar to ERIC, plus 'education' & 'learning.'

   Results: This search provided a few very good citations for the purposes of this study. As was expected the majority of the citations printed on the readout were too specialized for a cross-disciplinary study such as this.

5. PSYCHOLOGICAL ABSTRACTS (American Psychological Association) search on March 23, 1976. This data base provides world-wide coverage of journals, books, meetings, dissertations, etc., in psychology and related disciplines. It is indexed in monthly issues of Psychological Abstracts.

   The search keywords included: education, communication, instrumentation, electroencephalography, galvanic skin response, plethysmography and telemetry.

   Results: preliminary expectations, based upon listings found in the two index sources for this system (Psychological Abstracts and the Thesaurus of Psychological Terms), proved correct. Researchers in the field of psychology have made considerable use of the instruments of interest to this study. This was reflected in the index listings and in the quantity of useful citations appearing in the printout received from the PSYCHOLOGICAL ABSTRACTS computer search.

It should be added that all the above searches, except the Datrix Dissertation search, were done through terminals in the Michigan State University library.

A variety of other information sources were used, e.g. Dissertation abstracts and various indexes to periodical literature. Other sources were described in the two surveys of the literature described in Chapters 3 and 4.

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