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ABSTRACT

The paper describes an auto-tutorial methodology for training veterinary medical practitioners to perform differential diagnoses. It describes in detail the three phases of differential diagnosis: sensory pick-up, a combination of cognition and memory; categorization, the process by which diagnosticians group symptoms and signs prior to diagnosis; and inferential strategy, a combination of what diagnosticians refer to as intuition and confirmation techniques. The paper criticizes traditional methods of classroom instruction in differential diagnosis which present practitioners with informational cues in single disease categories in symptom-grouped fashion rather than in multiple disease categories characteristic of real-life situations. Students instructed in traditional methods when confronted with a real diagnostic problem must first complete a transfer from the learned system of information (single disease categories) to the alternative system (multiple disease categories) before diagnosis can take place. The paper briefly reviews a pilot study, utilizing both graduate and undergraduate veterinary medical students, which yielded data tending to verify the transfer hypothesis. Through an understanding of the differential diagnostic process, however, simulation exercises can be constructed to teach the organization of information into multiple disease categories and the inferential skill required to utilize the multiple disease categories to reach tentative diagnoses. (Author/JR)

UNDERSTANDING THE PROCESS OF DIFFERENTIAL DIAGNOSIS: PREREQUISITE TO THE TRAINING OF MEDICAL AND VETERINARY MEDICAL PRACTITIONERS

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by

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ABSTRACT

This paper is the result of the author's attempt to design an auto-tutorial methodology for training veterinary medical practitioners to perform differential diagnoses. An understanding of the process of differential diagnosis was considered prerequisite to the design; hence, the author's development of a conceptual model describing the process.

The paper briefly defines the component parts of the diagnostic process and then focusses on that portion of the process often labelled by diagnosticians as "intuition", "insight", or the "aha phenomena." The model incorporates Jerome Bruner's research with concept attainment and links the "intuition" in the process to Bruner's *focussed reception strategy*.

The proposed concept attainment model implies that a practitioner of differential diagnosis must be able to recall a system of relevant information (symptoms and diseases) which differs from the system learned during his or her undergraduate years in medical or veterinary medical school. Hence, it is hypothesized that a student confronted with a real diagnostic problem must first complete a *transfer* from the learned system of information to the alternative system, before the diagnosis can take place. As a result of more errors in recall and more time required for diagnostic decisions, the *transfer effect* culminates in inferior diagnoses.

The paper briefly reviews a pilot study utilizing both graduate and undergraduate veterinary medical students. The study yielded data tending to verify the *transfer* hypothesis and suggesting educational implications for both the undergraduate student and the medical <u>or</u> veterinary medical practitioner.

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INTRODUCTION

The theoretical model presented in this paper represents a portion of the author's Master's dissertation[1](1970). The study was originally conceived to develop an effective instructional strategy for differential diagnosis. However, very early in the study it was realized that little effort prior to the study had been directed at exploring the complex decision-making processes employed by medical and veterinary practitioners enabling adequate diagnoses.

Some of the most fruitful studies occurred in the late 1950s[2] and early 1960s[3] when efforts were directed at developing computerized differential diagnoses. However, models used in these studies were able to capitalize on the computer's capability to rapidly recall one hundred percent and quickly reach a diagnostic solution, regardless of the length and complexity of the strategy used. The problem is that man does not have one hundred percent recall capabilities and the strategy he employs to reach a diagnosis must not require excessive intellectual strain while still enabling him to reach both an accurate and rapid diagnosis.

In a more recent study Kleinmuntz[4] has applied computer technology to study the process of clinical diagnosis in psychology. In this study, Kleinmuntz employed an elaborate procedure to select an expert clincial psychologist, highly proficient at diagnostic evaluation. The psychologist was required to solve a number of diagnostic problems and encouraged to think "out loud." On the basis of this data a series of decision rules or "rules of thumb" were isolated and incorporated into a computer program which when run, performed initially as well as the diagnostician. Eventually, with some modifications, the computer's diagnostic performance exceeded the performance of the clinical psychologist. Wortman[6] selected a well known clinical neurologist to "think out loud" while solving a number of diagnostic problems. Again, the information processes and diagnostic rules were incorporated into a computer program of the diagnostic process in medicine and culminated in a program capable of performing diagnoses.

Other methodologies used in recent years to study the process of differential diagnosis range from those involving direct personal introspection as employed by Feinstein[7] to procedures involving the monitoring of mock medical workouts as used by Elstein, *et. al.*[8] The model presented here describing the inferential portion in process of differential diagnosis is based in well tested information-processing theory. However, for the most part, the degree to which the model represents the process employed by diagnosticians in the field, remains untested.

The theory put forward in this paper is aimed at describing the inferential process employed by diagnosticians during the information processing. To put the inferential process into perspective, it became necessary to outline a simple conceptual model for the overall process of differential diagnosis.

I. THE PROCESS OF DIFFERENTIAL DIAGNOSIS

The discussion in this paper circumscribes three primary facets of differential diagnosis--"sensory pick-up", "categorization", and "strategy." Although it is the concern of this study that the whole process be investigated, this paper will focus on the processes of categorization and the inferential strategy used to reach a tentative diagnosis.

A. SENSORY PICK-UP

R. Ledley and L. Lusted[2] describe several ingredients that belong to the process of diagnosis, the first of which is the group of signs and symptoms presented by the patient, and the second of which is the medical knowledge that the diagnostician possesses. Both the input from the patient and the knowledge that the physician has, are involved in the process referred to here as "sensory pick-up." In fact, the process might be broken down into two of the intellectual operations described by J.P. Guilford--"Cognition" and "Memory."[9]

The operations of Cognition and Memory work in the sensory pick-up process in the following manner:

Cognition is defined by Guilford as "awareness, immediate discovery or rediscovery, or recognition of information in various forms; comprehension or understanding." Thus, as the patient is observed, the cognitive operation is active and the sensory pick-up commences.

<u>Memory</u> is defined by Guilford as "the retention or storage, with some degree of availability of information in the same form in which it was commited to storage and in connection with the same cues with which it was learned." The memory operation begins almost immediately--first with a recall function and later with its storage function. Pieces of information are recalled as criteria for comparison with all new inputs. Thus a decision can be made as to what group the new input fits into to allow the new information to become meaningful.

Any improvement in the cognitive and memory abilities as a result of experience or some kind of training, would indeed improve the ability of the practitioner to perform differential diagnoses. However, the purpose of this study is not to focus on the intricacies of the sensory pick-up process, but merely to describe the relation of the sensory pick-up process to the whole process of differential diagnosis.

B. CATEGORIZATION

<u>Why Categorize?</u>

Bruner, Goodnow and Austin(10) describe what appears to be a paradox:

> The world of experience of any normal man is composed of a tremendous array of discriminably different objects, events, people, impressions. There are estimated to be more than 7 million discriminable colors alone, and in the course of a week or two we come in contact with a fair proportion of them. No two people we see have an identical appearance...All of these differences we are capable of seeing for human beings have an exquisite capacity for making distinctions.

But were we to utilize fully our capacity for registering the differences in things and to respond to each event encountered as unique, we would soon be overwhelmed by the complexity of our environment.

Consequently, individuals must categorize to render discriminably different things equivalent, and to group the objects and events around us into classes. Thus individuals can respond to them in terms of class membership rather than their uniqueness. Here it must be recognized that such categories exist only because they have been invented for our convenience. They exist as inventions, not as discoveries.

Bruner, *et. al.*[10] discuss fairly extensively the advantages achieved through the process of categorization and they are briefly described below:

1) Categories reduce the complexity of the environment.
2) Categorization is the means by which the objects of the world about us are identified. Thus there is the facilitation of communication.
3) Categories reduce the necessity of constant learning, as one is able to fit "new" items into "old" familiar categories.
4) Categorization provides direction for instrumental activity. Therefore, after fitting a new, unfamiliar item into an old familiar category, one can predict the qualities of the new item and adjust his behavior accordingly.
5) Categorization allows for ordering and relating classes of events. One relates different classes of events to form "systems" and thus draws meaning from the world around oneself.

When a category is formed it is identified by a trait common to all members of the category. The common trait that distinguishes this category from others is referred to as the "defining attribute" of that category and serves as a "label" for the category.

Probability Theory and Categorization

The process that allows comparison to take place between the new input (via Cognition) and the old experiential information (via Memory), is referred to as "Evaluation."

Evaluation, as such, is defined by Guilford[9] as "a process of comparing a 'product' of information with 'known' information according to logical criteria, and reaching a decision concerning criterion satisfaction." It is the experiential information recalled from the memory operation that serves as the criterion for comparison with the new information.

Towards the end of the evaluation operation, the decision-making process becomes involved and a decision made as to whether the new input is the same as the criterion (old information) or not. It is at this point, that the new input is placed into a meaningful group and categorization takes place.

Although the role of "probability" is not to be investigated extensively in this study, it does play a vital role in the process of categorization during differential diagnosis.

The evaluation operation always involves the use of some sort of criteria as a decision-making base. The problem arises when the criteria are to be selected, and it is here that the probability factor enters the process, regardless of when the evaluation operation takes place. For example, in differential diagnosis, at one stage it is necessary to recall a criterion considered by the diagnostician to be a normal state, and then compare it with the new input to determine if the new input can be considered normal. However, the question must be continually asked, "how normal is the 'normal' criterion?" Variables such as geography and time must be considered during the criterion selection. For example, what may be a satisfactory "normal" in one set of environmental conditions, may in fact not be a suitable "normal" criterion in another set of environmental conditions. Consequently, past experience must be referred to, to furnish a probabilistic guess, and as each new input is encountered and added to experience, the probability base for some decision will be altered.

Elstein *et. al.* postulate the existence of four principles used by physicians to rank-order the hypotheses for a given diagnostic problem. The study suggests that physicians employ probability as one of the principles and that "subjective estimates are made of the statistical likelihood that a particular disease is causing the patient's problem. The estimate may closely approximate the population base-rate for a disease."

As a result of attempts to program computers to perform differential diagnoses, the need for probabilistic concepts has been recognized. Such concepts were first applied to differential diagnosis by Ludley and Lusted,[2] in the form of Bayes Formula. A modification of Bayes Formula by Warner, Toronto, and Veasy[11] in 1965, was proposed as a result of the application of Bayes Theorem to the diagnosis of congenital heart disease.

It should be noted here, that Feinstein[12] expresses severe reservations about the excessive use of statistical mechanisms for reasoning in the process of differential diagnosis.

However, whenever the evaluation operation is active, there is a comparison to some criteria to enable a decision to be made. It is at this point that probability theory, based on experience, must affect the decisions made.

Categorization and the Diagnostic Process

The question then becomes: "how does a diagnostician categorize new information that reaches him as he proceeds to solve a diagnostic problem?" Wortman[12] found that medical students organized disease information in clincial neurology into about ten mutually exclusive, but complete categories. Every neurological disease fell into a category, and only one category. Feinstein[7] defines the clinical domain as a category representing that portion of the body that is the structural or functional source of a disease manifestation or sign. Since clinical specialities tend to frequently orientate around specific domains McWhinney[14] cites such specialities as examples of how diagnostic information tends to be grossly categorized. For example the otolaryngologist assumes that he will encounter ear, nose and throat problems and omits a pelvic examination, while the gynaecologist for similar reasons does not usually examine either ears or throat. Mandler[15] has developed a theory concerning the organization of information and memory. In his theory Mandler describes information as being successively grouped or categorized and then recategorized into larger groups forming hierarchial structures. Furthermore, Wortman and Greenberg[17] conducted a study employing common objects and their descriptions rather than diseases and the symptoms that are characteristic of them and concurred with Mandler's findings. Finally, the Elstein *et. al.*[8] study demonstrated that the experienced physician quickly develops a small array or category of possible hypotheses as potential solutions to a given diagnostic problem.

Reference literature available to diagnosticians, generally groups or categorizes symptoms and signs according to single disease entities. For example, the name of the disease is provided, followed by an extensive description of the disease, which in fact, is a list of signs and symptoms that occur when that disease is present. Thus information is presented in a "symptom grouped" format with the disease name serving as the label or defining attribute for the group of symptoms and signs. For example, in Figure A(i), page 3, the disease is described by the group or category of symptoms--1, 2, 3, 4, 5, 8, and 13.

Categorization of Diseases and Symptoms

Key: A B C D . . . diseases
1, 2, 3 symptoms and signs (defining attributes or labels)
[box] - - - category
[arc] - "and/or"

Figure A(i) Symptom-Grouped referred to as Single-Disease Categories (SDC)

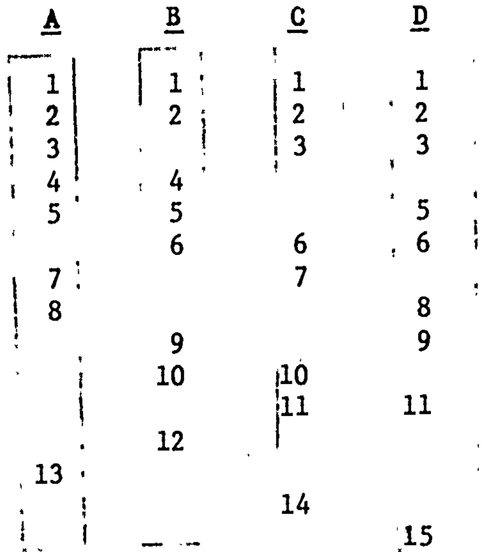


Figure A(ii) Disease-Grouped

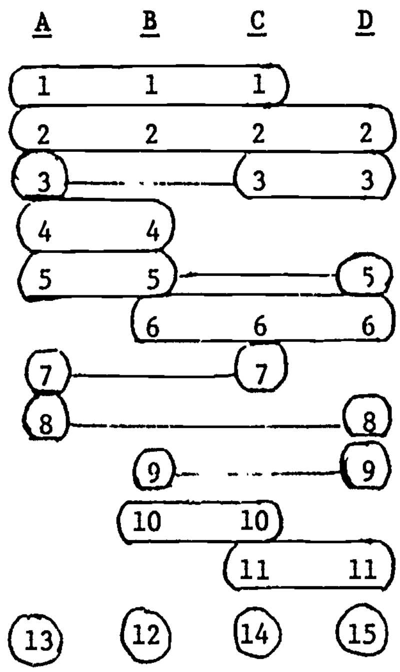


Figure A(iii) Disease Categories referred to as Multiple Disease Categories (MDC)

2 (symptom or sign that serves as the category label or defining attribute)

$A \cap B \cap C \cap D$

1 3 6 5

$A \cap B \cap C$ $A \cap C \cap D$ $B \cap C \cap D$ $A \cap B \cap D$

4 7 8 10 9 11

$A \cap B$ $A \cap C$ $A \cap D$ $B \cap C$ $B \cap D$ $C \cap D$

13 12 14 15

A B C D

Henceforth, this study will refer to the separate categories of signs and symptoms as found in the reference literature, as information in the "symptom-grouped" or the Single Disease Category format.

However, the practitioner upon confronting his patient, is faced with a much different situation. In fact, the practitioner has available to him the signs and symptoms of many disease entities and he must narrow down the disease possibilities and identify the correct disease or disease complex. Thus the practitioner is faced with a different categorization format, where the symptoms and signs become the label or defining attributes for "disease groupings" as illustrated in Figure A(ii) and Figure A(iii), on pages 8 and 9.

For example, symptom 2 occurs in each of the diseases A, B, C and D. Therefore, the presence of symptom 2 could indicate the existence of any combination or all of the diseases A, B, C, and D. Henceforth, this paper will refer to such disease groupings as Multiple Disease Categories (MDC).

C. STRATEGY

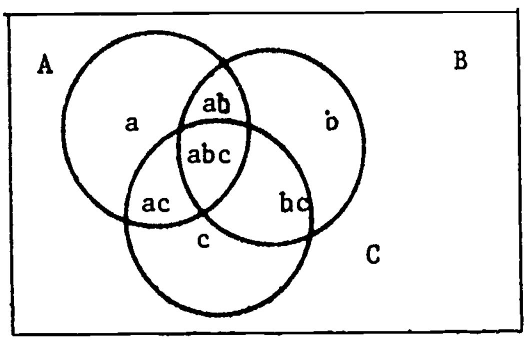
The "Aha" or Hunch Phenomenon Alias Intuition, Art, Focussing Reception Strategy(10)

When practitioners are questioned as to their process for diagnosing, the process is commonly referred to as an art and some practitioners are better at diagnosing than others simply due to either innate or developed intuitive qualities. It would appear that the good diagnostician frequently capitalizes on hunches and the feelings generated soon after his or her initial exposure to the problem. These early hunches or insights are in fact treated by the diagnostician as a tentative diagnosis upon which he or she acts with deliberate precision to search for signs or symptoms that may either confirm or infirm the tentative diagnosis or hunch. This author disagrees with the suggestion by Elstein *et. al*[8] that their study results are contradictory to findings in the concept attainment literature. Although some of the data may indeed appear to contradict concept attainment findings, the purpose of this paper is to describe the "aha" phenomenon referred to by Bruner *et. al.* as the *focussed reception strategy*. Whereas the Elstein *et. al.* findings suggest the physician's early arrival at a small array of hypotheses and a subsequent rank-ordering of these hypotheses on the basis of such principles as probability, seriousness, treatability and novelty, this paper proposes that a physician's hunch as arrived at through an inferential process will be a major factor determining which hypothesis he selects to examine first.

Figure B below is comprised of three intersecting circles: a, b and c, and represents the interrelationship of the signs and symptoms of the three diseases A, B and C.

Figure B

Signs and Symptoms of Diseases A, B and C



The areas, both shared and unique to the three circles, represent the signs and symptoms of diseases A, B and C. Some of the signs and symptoms are elicited by all three diseases, some are demonstrated by two of the diseases, and some signs are unique to only disease A, only disease B, or only disease C.

For example, the area abc represents those signs and symptoms demonstrated by all three diseases A, B and C, but not demonstrated by any other diseases with which the diagnostician is familiar. The signs represented by the area ab are those elicited by diseases A and B with ac and bc representing signs elicited by diseases A and C, and B and C respectively. The unique signs and symptoms a, b and c, are those signs that if present, immediately indicate the presence of the disease they represent.

As the practitioner begins to diagnose he finds it relatively simple to eliminate most of the disease universe (the universe is a set of all of those diseases with which the diagnostician is familiar); however, as the diagnostician works towards a tentative diagnosis, he or she must make finer and finer discriminations and continue to eliminate diseases to reduce the alternative solutions to the problem. Ultimately, the practitioner is left with a few very similar alternatives demonstrating similar signs and symptoms. However, as the process of elimination continues and discrimination between diseases becomes more difficult, the less intuitive practitioner begins to actively search for the unique signs or symptoms of the alternative diseases facing him. Only in this way is he able to establish the final diagnosis. However, depending upon when the active search is implemented, time will be wasted in unsuccessful searches, for in many instances unique signs and symptoms confirming the final diagnosis will continue to evade the diagnostician simply because he or she must explore each of the diseases as if it were a tentative diagnosis.

If on the other hand, the diagnostician is able to carry the intuitive discrimination process to its end and develop a hunch or tentative diagnosis involving only one possibility, then an active search to confirm the tentative diagnosis will be much easier. With a one disease hunch or tentative diagnosis the diagnostician can actively search for the unique signs normally demonstrated by the one disease. Thus, he has a much greater chance of locating the signs and confirming the tentative diagnosis. Hence, the fewer the number of disease alternatives the diagnostician has to explore before he begins his active search for unique signs or symptoms, the greater his or her chances of both an accurate and rapid diagnosis.

The process the diagnostician follows to discriminate between diseases and develop his hunch, is a relatively fast process in that the diagnostician follows a routine examination procedure picking up as many signs and symptoms as he can along the way. Suddenly a hunch occurs and a tentative diagnosis is made. The question that must be asked then is - what is this process that has occurred which has allowed the diagnostician to develop his or her hunch?

In Figure C(i), the diagnostician picks up the signs and symptoms abc that occur only in diseases A, B and C. The presence of the symptom abc tells him that the tentative diagnosis is either A, B, or C and that all other possibilities have been eliminated. If the sign ab is picked up, then the tentative diagnosis must be either A and/or B with C being eliminated. Finally, if the sign ac is picked up, the suggestion is that the tentative diagnosis must be A and/or C with B eliminated. However, up to this point both C and B have been eliminated along with the rest of the universe, hence the tentative diagnosis must be A. It is at this point that the diagnostician begins to actively search for the unique signs and symptoms normally demonstrated by disease A.

Figure C

The "Aha" Process or Focusses Reception Strategy

	Sign or symptom	Diagnosis alternatives presented in symptom cue	Disease alternatives eliminated	Remaining disease alternatives
i)	0	a∩b∩c∩d∩α	0	0
	1	a∩b∩c	D→α	A∩B∩C
	2	a∩c	B	A∩C
	3	a∩b	C	(A)
ii)	0	a∩b∩c∩d∩e∩α	0	0
	1	a∩b∩c∩g	D,E,F,H,J→α	A∩B∩G
	2	b∩c∩f∩g	A	B∩G
	3	a∩g∩h	B	(G)

Key: ∩ - "and/or"

◯ - tentative diagnosis

Systematic Collection of Diagnostic Information Alias Confirmation Strategy

Bruner, et. al[10] refer to the process as validating or confirming by means of recourse to some ultimate criteria. In the case of differential diagnosis the ultimate criteria used to confirm a tentative diagnosis are the uniqe symptoms of the diseases. tentatively diagnosed. For example, in Figure C(i), the hunch or tentative diagnosis is disease A; therefore, the confirmation strategy then is the search the practitioner goes through to determine if the unique signs or symptoms of disease A are present. If they can be found, the hunch or tentative diagnosis will have been confirmed.

The confirmation strategy can become active at any point in the hunch or focussing reception process. However, it is most efficiently utilized after the reception strategy has been carried as far as possible so that the tentative diagnosis is narrowed down to as few alternative diseases as possible.

A Model for Differential Diagnosis

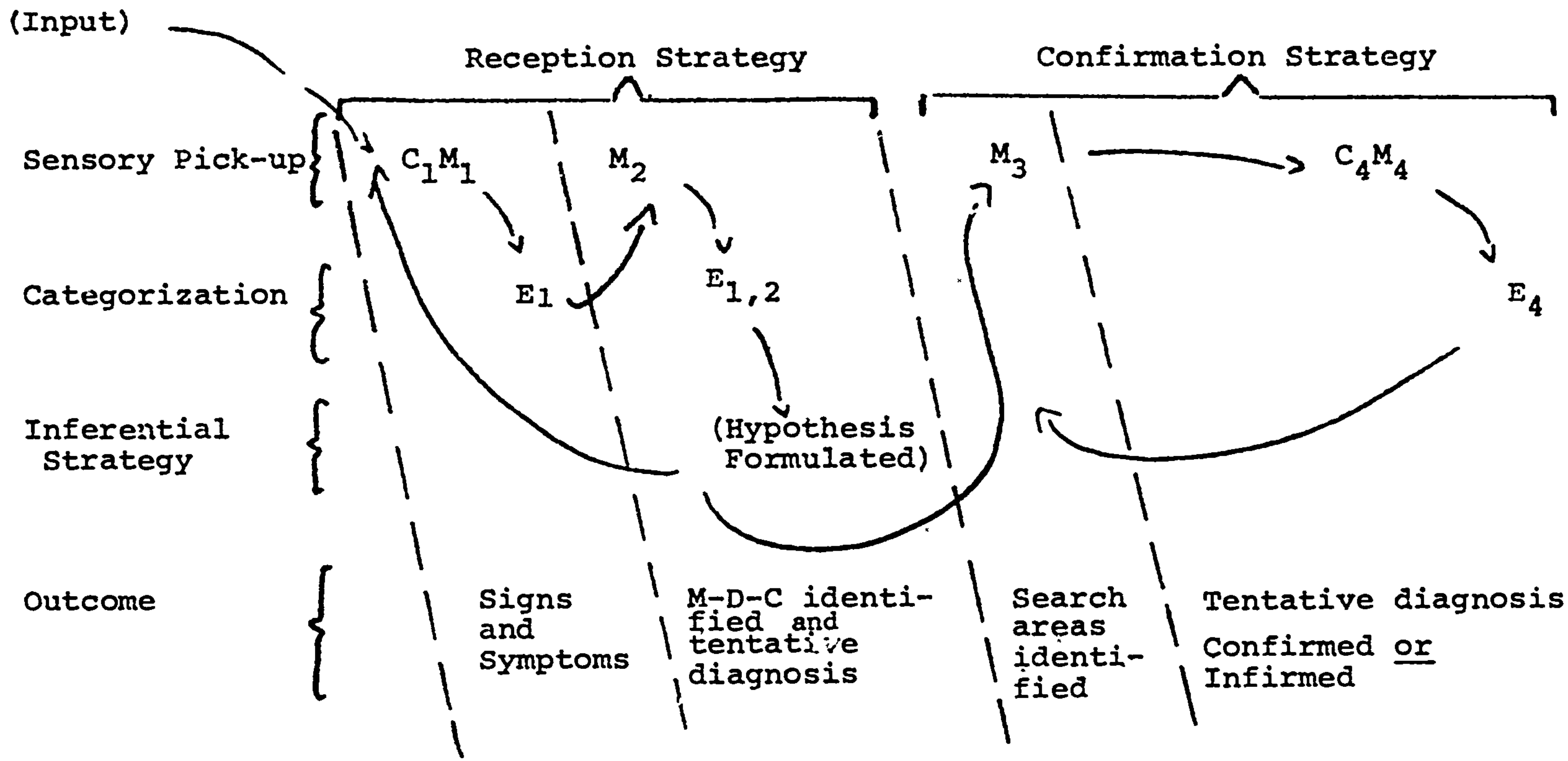
A model describing the overall process of differential diagnosis is illustrated in Figure D on page 17, and it would appear useful to describe the specific stages in the process model, as they appear in chronological order.

C_1 M_1stage: C_1 represents the first instance of Cognition (C) resulting in a subsequent environmental input into the process; sensory cues such as signs and symptoms are recognized and picked up at this point.

M_1 represents the first instance of Memory (M) resulting in recall of past experiential inputs. Of primary concern here, is the recall of what the "normal" state is and it is this information that becomes the criteria for later comparison with new cues picked up in C_1. It should be noted at this point, that M_1 also operates to store information.

Figure D

A Process Model for Differential Diagnosis



E_1 stage: E_1 represents the first instance of Evaluation (E) which in turn involves:

a comparison of C_1 and M_1 results;

using M_1 recall as the criteria for making a decision as to how "normal" the input is;

the input is then considered categorized as "normal" or "abnormal";

an "abnormal" input is referred to as a symptom or a sign.

M_2 stage: The Memory (M) operation is activated again to recall the diseases or the Multiple Disease Category that elicit that sign or symptom.

$E_{1,2}$ stage: The new symptom is compared with the symptom recalled as the defining attribute for a specific Multiple Disease Category. The symptom recalled serves as the criteria for the evaluation. A decision is made to determine if the new symptom meets the criteria ("is the new symptom the same as the recalled symptom?"). If the new symptom then meets the criteria, or is the same as the recalled symptom, it is categorized the same as the criteria and becomes a defining attribute or label for the same multiple disease category. That is, the new symptom and the category it represents is the same as that recalled. However, if the new symptom does not meet the criteria, further recall from M_2 is needed to allow for identification of the new symptom or else the new symptom is ignored.

Hypothesis formation stage: This stage usually takes the form of the Focussing Reception Strategy described earlier, and decisions are made as to:

(1) what diseases are included in the newly identified Multiple Disease Category (MDC);

(2) what diseases are eliminated by the newly identified MDC;

(3) what alternative diseases remain as candidates for the tentative diagnosis (new hypothesis).

After the new hypothesis is formulated, the entire process recycles until either a single tentative diagnosis is reached or the inputs cease to supply Multiple Disease Categories that can be used to further narrow the tentative diagnosis to fewer diseases.

Thus ends the "Aha" process otherwise known as the focussed reception strategy. Whereas, with the focussing reception strategy the diagnostician plays a relatively passive role in the physical sense, he plays a much more active role in the confirmation strategy upon reaching the tentative diagnosis.

M_3 stage: The confirmation cycle is initiated with the memory operation which is used to recall the unique symptoms elicited by the diseases articulated in the final hypothesis in the reception cycle. The unique symptoms in turn are used to recall physiological areas where the unique symptoms are located. The diagnostician then begins an active search of those areas recalled in M_3.

C_4 M_4 stage: C_4 represents the cognitive operation inputs as the search is being conducted.

M_4 represents recall of the same material as recalled in M_3, only for a different reason. In M_3 the unique symptoms of the disease(s) identified in the tentative diagnosis were recalled to determine where the practitioner should look for the same; however, in M_4 the unique symptoms are recalled as a set of criteria in order that they may be compared with the signs arising from the outcome of the search.

E_4 stage: This stage represents a comparison of the new inputs from C_4 with the criteria recalled in M_4 to decide if the new inputs (signs and symptoms) match the criteria. If the new input C_4 matches the criteria from M_4, it is then categorized as confirming or infirming the tentative diagnosis reached in the earlier reception cycle. The confirmation cycle then repeats itself so that each of the cues (C_4) are examined and compared (E_4) with the criteria recalled (M_4) and a judgment is made as to how well the inputs (C_4) match the criteria (M_4).

II. EDUCATIONAL IMPLICATIONS: CLASSROOM VERSUS THE REAL WORLD

A. LEARNING NODES

It would appear from the model diagrammed in Figure D page 17 of this paper for the process of differential diagnosis, that five areas of study are required to facilitate effective diagnoses: cognition, memory, evaluation, the "Aha" phenomenon, and confirmation techniques.

Cognition

Cognition as defined by Guilford[9] is "awareness, immediate discovery or rediscovery, or recognition of information in various forms: comprehension or understanding." Thus, as the patient is observed the cognitive operation is active and the sensory pick-up commences.

The greater the practitioner's ability to carry out the cognition operation, the greater the number of cues that will be received and hence the greater the information that will be plugged into the diagnostic process. Thus the greater the cognition skill the greater the chances of a successful diagnosis.

Memory

Memory as defined by Guilford[9] is "the retention or storage with some degree of availability of information in the same form in which it was commited to storage and in connection with the same cues with which it was learned." The memory operation begins almost immediately - first with a recall function and later with a storage function. Pieces of information are recalled as criteria for comparison with all new inputs. Thus a decision can be made as to what group the new input fits into to allow the new information to become meaningful. Obviously the better the memory of a practitioner, the better his chances for a successful diagnosis.

Evaluation

Evaluation as defined by Guilford[9] is a "process of com ng a product of information with known information according to a logical criteria, and reaching a decision concerning criteria satisfaction." It is the experiential in rmation recalled from the memory operation that serves as the criterion for comparison with new information.

Thus the better a diagnostician is at performing the evaluation operation, the greater his/her chances of a successful diagnosis. However, it is not only important that he or she be able to compare the new information with a set of criteria but that he or she be able to utilize probability theory effectively in the diagnostic process. That is, the practitioner must be able to accurately estimate the odds when determining what is the "normal" required to serve as the criterion.

The "Aha" Phenomenon

The "Aha" phenomenon is defined in this paper as the organization of multiple disease categories followed by the inferential strategy applied to the multiple disease categories to reach an initial hunch or intuitive diagnosis. Furthermore, this paper proposes that it is synonymous to the focussed reception strategy proposed by Bruner *et al.*[10]

One might assume that if the "Aha" phenomenon occurs as described in this paper then an increase in skill at organizing multiple disease categories and applying inferential strategy to these categories would result in faster and more accurate diagnoses.

Confirmation Technique

Confirmation technique can be defined as the technique the practitioner applies as he or she goes through the process of confirming or infirming the tentative diagnosis arrived at earlier in the diagnostic procedure. The technique the diagnostician uses to expose cues and signs which may in fact confirm the tentative diagnosis is no doubt a skill that can be learned and developed.

The above five learning nodes are areas with which the student of differential diagnosis should be familiar. Furthermore, educators in the area of differential diagnosis should be constructing learning experiences designed with specific objectives to develop competencies in each of the above learning nodes.

B. LEARNING THE "AHA" PROCESS

The "Aha" process or focussed reception strategy, requires a two step procedure: *the organization of multiple disease categories*, and the *application of inferential strategy* (focussed reception) to the multiple disease categories.

Organization of Multiple Disease Categories

Traditional classroom instruction of differential diagnosis and traditional literature used by students of differential diagnosis usually categorizes the information according to diseases. As illustrated in Figure A(i) page 8, the signs and symptoms of a specific disease can be grouped and their group or category labelled or identified by a specific disease name. For example, in Figure A(i), the disease A is the label applied to that group or category of signs and symptoms - 1, 2, 3, 4, 5, 7, 8, and 13.

Ideally, differential diagnosis would best be taught by exposing the students to real life situations. For example, the diseased patient, animal or plant, would be moved into the classroom. However, for obvious reasons this procedure is impossible in most instances. Therefore, the educator must attempt to simulate in the classroom, the real life situation. This in turn requires a thorough understanding of the process of differential diagnosis.

This paper proposes that in a real life situation, the informational cues required for the diagnostic process are not presented to the practitioner in a sympton-grouped fashion as they are presented in traditional instruction practices. This paper further proposes that in the real life situation the practitioner has to deal with informational cues presented in multiple disease categories as illustrated in Figures A(ii) and A(iii). That is, the practitioner recognizes the cue or symptom and identifies the array of diseases that that symptom demonstrates. That array of diseases is in fact a multiple disease category.

Therefore, the educational implications are that instructors of differential diagnosis should facilitate the organization of disease information into multiple disease categories. It is obvious then that when the instructor attempts to simulate the real field conditions, the symptom information should be presented in such a way as to encourage the student to organize disease information into multiple disease categories and utilize these categories to solve the diagnostic problems.

Currently the student is exposed to traditional instructional methods presenting symptom-grouped information. However, when he or she is confronted with a real diagnostic problem, the student finds him or herself reorganizing previously learned symptoms and diseases into multiple disease categories. This *transfer* from single disease categories to multiple disease categories is a strain on the student's ability to recall, which in turn will ultimately lead to less retention and a greater time for information recall. Thus, unless field conditions can be simulated, the student must wait for direct field experience to develop skill in organizing and using multiple disease category information.

Inferential Strategy (Focussed Reception)

Even after the student is capable of organizing and recalling information in the form of multiple disease categories, he or she must be able to utilize the multiple disease categories to reach the tentative diagnosis. This paper proposes that there is a skill involved in manipulating the multiple disease categories to arrive at a tentative diagnosis. As a skill, the process can be learned - hence the rationale for simulation exercises to teach differential diagnosis.

Simulation of a diagnostic problem should, as suggested earlier, present informational cues in the form of multiple disease categories and in a sequence that will lead the student through the informational process of logic towards a tentative diagnosis (as illustrated in Figure C page 15).

Thus, through a simulation exercise a student can learn to apply inferential strategy to utilize multiple disease category information to ultimately reach the tentative diagnosis.

Summary

This paper has proposed a model describing the process of differential diagnosis. It has also attempted to describe in detail that process frequently described by diagnosticians as "intuition."

Furthermore, the paper proposes that through a thorough understanding of the differential diagnostic process, simulation exercises can be constructed to teach the skills involved in differential diagnosis. Specifically, it proposes the use of simulation exercises to teach the organization of information into multiple disease categories, and the inferential skill required to utilize the multiple disease categories to reach tentative diagnoses.

R. C. Cabot,[18] an early pioneer in the process of differential diagnosis, called differential diagnosis:

> . . . a very dangerous topic--dangerous to the reputation of physicians for wisdom. It is, I suppose, owing to this danger that so little has been written on differential diagnosis and so much on *diagnosis* (non-differential). To state the symptoms of typhoid perforation is not difficult. To give a set of rules whereby the conditions which simulate typhoid perforation may be excluded, is exceedingly difficult. Physicians are naturally reticent on such matters, slow to commit their thoughts to paper, and very suspicious of any attempt to tabulate their methods of reasoning. Yet all diagnosis must become differential before it can be of any use.

Thus Cabot expressed fifty years ago a feeling of futility. Perhaps soon we will be able to view the process of differential diagnosis more as a science and less as an art.

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AERC/75 PAPER SUPPLEMENT

The "Trasnfer Effect": Some Preliminary Data

R. M. K. Wagner

PROBLEM

For purposes of this study, it was assumed chat in reality medical and veterinary practitioners confronted with a diagnostic problem quickly develop an array of possible hypotheses or solutions to the problem. In the preceding paper, the array of hypothetical solutions to a diagnostic problem was referred to as the initial multiple-disease category; hence, the assumption that in reality diagnosticians are confronted with disease and symptom information in the form of multiple-disease categories.

The purpose of this study was to collect preliminary data to assess the cognitive strain produced by the "transfer effect" and to determine if diagnosticians can effectively take information in the form of multiple disease categories and commit it to memory for later recall.

METHOD

Subjects

A group of 41 graduate and undergraduate veterinary medical students volunteered for the study. The subjects were divided into two groups with 20 subjects in the group receiving the traditional instructional treatment and 21 subjects in the group receiving the experimental treatment.

Instruments

The instruments were designed to simulate disease and symptom information. Four diseases were selected as the initial array of hypothetical solutions and were identified as diseases A, B, C, and D. For each disease a list of symbols was prepared to simulate the signs and symptoms elicited by the presence of the disease. Care was taken to ensure that the diseases A, B, C, and D had numerous sets of common symbols between them representing symptoms but with the ocassional symbol unique to a specific disease.

The treatment for the *traditional group* was designed to simulate diagnostic information that was symptom-grouped as it is frequently organized in reference literature and described in the preceding paper. Therefore, the instrument for the traditional treatment involved four packages of cards, with each package representing a single disease and containing the symbolic symptoms of that disease. A page of instructions was also prepared to accompany the treatment.

The purpose of the *experimental treatment* was to attempt to simulate the real diagnostic problems encountered by the practitioner. For this reason, the diagnostic information was presented on cards in the disease-grouped format as described in the preceding paper. The experimental treatment also involved the incorporation of a problematic schema in the form of a focussing reception strategy as described by Bruner *et. al.* for use in solving concept attainment problems. Consequently, the information was presented in the form of problems incorporating:

1. Disease-grouped information involving symbolic diseases with a symbolic symptom defining and identifying each disease group;

2. Problems in the form of the focussing reception strategy.

The experimental treatment involved the same symbols and diseases as the traditional treatment, but arranged in disease-grouped categories. As with the traditional treatment a page of instructions was prepared to be administered with the treatment.

The *test instrument* was designed to test the subjects' ability to recall the appropriate disease-grouped category after being presented with a particular symbolic symptom. The test instrument involved a series of 35mm color slides with each slide containing a symbolic symptom employed in both treatments.

Each subject was asked to record his/her response to each test item by pressing one or more of the buttons on a response panel placed before them. The four buttons were labelled A, B, C, and D after the four hypothetical diseases. Each response panel was connected to a polygraph to enable the author to determine whether or not the response was correct and to estimate the time required for the subject to respond.

Treatment

Each of the groups was provided with the appropriate set of written pre-treatment instructions along with treatment instruments. After the instructions were clear, each subject was allowed twelve minutes to work through the treatment and learn the information presented. The subjects were then tested by being asked to use the response panel to record as quickly as they could the diseases they thought were represented by each symbolic symptom presented. A maximum of 15 seconds was allowed for each response, with the subjects being encouraged to respond as quickly and as accurately as they could.

Limitations

The data collected in this study is of a preliminary nature to prepare for a comprehensive follow-up investigation. The number of test subjects was limited to a total of forty-one undergraduate and graduate students randomly divided into two groups of twenty and twenty-one each. The study results can therefore be only safely generalized to the formal student of differential diagnosis with limited diagnostic experience. A follow-up study should include a more representative sample of those practitioners confronted with diagnostic problems on a regular basis.

RESULTS

The mean score and time differences between the subjects exposed to the traditional treatment and the subjects exposed to the experimental treatment were calculated and an F-Test applied to determine if the population variance estimates were significantly different at the 5% level. When the two estimates were not significant, Fisher's t-test was applied; but when the estimates were found to be significantly different, Fisher's modified t-test was applied.

*TABLE I

Recall of Single-Disease Categories

[No transfer required]

Hypoth.	Tr.	Ex.	Signific. of difference
Score = $\bar{S}_{Tr.} > \bar{S}_{Ex.}$	1.7	1.4	@ .0005 level [99.95% real]
Time = $\bar{T}_{Tr.} < \bar{T}_{Ex.}$	2.7	5.4	@ .005 level [99.5% real]

*TABLE II

Recall of Multiple-Disease Categories

[Transfer required for Tr. group only]

Hypoth.	Tr.	Ex.	Signific. of difference
Score = $\bar{S}_{Tr.} < \bar{S}_{Ex.}$	4.1	4.3	Diff. <u>not</u> signific. @ .1 level
**Time = $\bar{T}_{Tr.} > \bar{T}_{Ex.}$	5.5	4.4	@.0005 level [99.95% real]

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*Key = $\bar{S}$.....mean score (no. of correct decisions)

$\bar{T}$.....mean time (per correct decisions)

Tr....group receiving traditional instruction

Ex....group receiving experimental instruction

$>$...greater than

$<$....less than

**Transfer time

Because a Type I error was not to be considered as serious for this preliminary assessment, it was decided to adopt the ten percent probability level with a one-tailed test, as the level to be used to determine whether or not the differences were significant.

As illustrated in Table 1, the traditional group performed significantly better than the experimental group at recalling single-disease categories. Single-disease categories are those categories that contain only one disease for a given symptom; therefore, involving the unique symptoms found in one, and only one disease. The subjects exposed to the traditional instructional treatment and attempting to recall a single-disease category were <u>not</u> required to transfer to a multiple disease category, since no multiple-disease categories were involved.

Table II illustrates the findings when the two groups were asked to recall multiple-disease category information. For this task, all of the subjects receiving the traditional instructional treatment were required to perform a *transfer* from the symptom-grouped information to the disease-grouped information in order to recall the appropriate multiple-disease categories. Although the experimental group appeared to perform better than the traditional group with respect to the number of correct recalls, this difference was <u>not</u> significant at the predetermined 0.1 level. *However, the traditional subjects required significantly more time to respond correctly then did their experimental counterparts.*

DISCUSSION

It was anticipated that the traditional subjects would perform as well or better than the experimental subjects when given a task to recall single-disease categories where transfer was not required. The explanation for the hypotheses being upheld for the subject's recall of single-diseased categories is two-fold:

1. No transfer was required thereby adding no additional strain to the group exposed to the traditional instructional treatment;

2. One might suspect that subjects in the traditional group would proceed with the learning task as they would in a classroom and immediately locate the unique characteristics of each disease that differentiates that disease from the other three; hence, the traditional group likely paid more attention to the unique symptoms or single-disease categories.

An obvious explanation for the Score hypothesis not being upheld in the task involving *recall of multiple-disease categories* is that the experimental group was exposed to an additional problem-solving task as well as the task of learning the appropriate mutliple-disease category information. This dual task arrangement may have created sufficient cognitive strain to effectively reduce the experimental group's ability to memorize and retain multiple-disease category information. Therefore, in the test, the additional task given the experimental group may have compensated for the traditional group's need to transfer from one system to the other.

It should be noted though, that the Time hypothesis was upheld with a significant difference between the traditional and experimental group. One explanation for the difference in time would be that the subjects receiving the traditional treatment required the extra time to transfer from the symptom-grouped format to the disease-grouped format to recall the multiple-disease categories. This evidence then suggests that the transfer does indeed take place and was a handicap imposed on the subjects exposed to the traditional instructional treatment.

It is possible that the test treatment incorporated in the study did not put sufficient strain on the subjects. The subjects were asked to respond as quickly as possible and still arrive at a correct response within the outside time limit of 15 seconds. However, from the observations one would suspect that if the maximum time allotted was reduced substantially, the subsequent strain imposed upon the traditional subjects attempting to perform the transfer, would culminate in the traditional subjects scoring at a significantly lower level then the experimental group.