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ABSTRACT

Hypothesis generation has been proven to be a crucial phase in the clinical inquiry. The current instruments for measuring clinical problem-solving skills, however, are unable to differentially assess the hypothesis generating ability. For assessing this particular capability a new test is described. It is based upon exposing the examinee to an unrealistic, hypothetical, and thus unfamiliar context. A wide range of alternative data are presented, from which the examinee is required to choose those which fit his or her hypothesis, avoiding internal inconsistencies. Construct validation, both discriminant and convergent is presented, demonstrating independence of the test on the depth of the knowledge of the content areas from which it is derived; at the same time achieving significant correlation with the scores on patient-management-problems (PMP). This later correlation increases as the PMP further diverges from the recognizable reality. Some variations of the "unrealistic simulation approach" are proposed. These may correspond with the various stages in the medical education. It is suggested that this test be used as a supplementary to the PMPs. (Author)

UNREALISTIC SIMULATION APPROACH FOR MEASURING PROBLEM-SOLVING SKILLS OF MEDICAL STUDENTS

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ABSTRACT

Hypothesis generation has been proven to be a crucial phase in the clinical inquiry. The current instruments for measuring clinical problem-solving skills, however, are unable to differentially assess the hypothesis generating ability. For assessing this particular capability a new test is described. It is based upon exposing the examinee to an unrealistic, hypothetical, and thus unfamiliar context. A wide range of alternative data are presented, from which the examinee is required to choose those which fit his or her hypothesis, avoiding internal unconsistencies. Construct validation, both discriminant and convergent is presented, demonstrating independence of the test on the depth of the knowledge of the content areas from which it is derived; at the same time achieving significant correlation with the scores on Patient-management-problems. This later correlation increases as the PMP further diverges from the recognizable reality. Some variations of the "unrealistic simulation approach" are proposed. These may correspond with the various stages in the medical education. It is suggested that this test be used as a supplementary to the PMPs.

Clinical simulations have become recently a rather frequently used tool for both instruction and evaluation in medical education. McGuire et al (1976), pioneers in the field, define a simulation as a reflection of the reality reduced to its essence, in which the learner (or the examinee) is confronted with a problematic situation and is required to embark upon a series of inquiries, decisions and actions.

This 'realistic' technique has both strengths and weaknesses, which derive from the fact that it is designed to approximate a given reality. The advantages of using it for evaluation has been extensively described elsewhere and include: perceived relevance; standardization of the task; a wide range of sampling of competencies; objective ratings; and fast feedback (McGuire et al, 1976; Neufeld, 1977). Even more significant is some evidence of its criterion validity,(McGuire & Babbott, 1967), although this issue is still debatable (Goran et al, 1973). The disadvantages which have been described include a difficulty in simulating some aspects of the reality, and an incomplete measurement of some competencies as, for example, factual knowledge (McGuire et al, 1976). It is suggested that the simulation technique may have two additional limitations, both stemming from the concept of reflecting reality: a limited or impossible utilization of the instrument in the early phases of medical education; and confounding of the mental processes involved in problem-solving.

In order to measure performance in a simulated reality, the learner has first to acquire a good grasp of that reality. Posing a realistic clinical problem to a freshman student within the framework of a traditional curriculum will be either highly irrelevant, or unrealistic, or both. Thus the use of the technique is confined to the later phases of medical education. However, the acquisition of problem solving skills in the early, formative years is regarded as of an utmost importance (Dewey, 1916; Neufeld, 1977) and some schools have adopted an interdisciplinary integrated problem-solving approach from the commencement of studies (Neufeld, 1977; Bouhujis et al, 1978; Benor et al, 1979).

The second limitation of the simulation technique, also stemming from its realism, is of greater concern. The mental processes involved in problem-solving have been recently illuminated through extensive research. Guilford and Hoepfner (1971) suggested a four-stage process including: memory operations; divergent production; cognition; and evaluation operations. These roughly correspond to the findings of Elstein and his collaborators (1978), who defined the four stages of clinical inquiry in terms of: cue acquisition; hypotheses generation; cue interpretation; and hypotheses evaluation. Culter (1979) recently has described a variety of strategies used in the process of problem-solving. However, there is a uni-phasic 'short cut', entitled by the two last authors as pattern recognition or pattern matching which is widely used by practitioners on numerous occasions. This more economical heuristic process is a recognition of a pattern, syndrome or cluster of cues, which give rise to an almost reflexive response.

Contemporary medical education aims at developing the clinical inquiry approach (Elstein et al, 1978), which is systematic and analytic in nature. Heuristic 'jumps', as the pattern recognition, are permitted insofar as they are later analytically evaluated; cue recognition should be preceded by active cue acquisition, and supplemented by cue interpretation. Herein lies the difference between the apprenticeship approach of the old days, aimed at increasing the pattern repertoire of the learner in order to enable acquisition of readily recognized sets and reflexive responses, and the post-Flexnerian approach. The present communication suggests that the realistic simulation technique cannot differentiate between the analytic and the heuristic modes of thinking. It is further suggested that a differentation is needed both for educational planning, and for diagnostic purposes of identification of students who require remedial intervention. It is particularly required in the early phases of education, when thinking habits are internalized.

Following is a presentation of an 'unrealistic simulation' technique designed and utilized especially for the evaluation of the hypothesis generation stage of the problem-solving process. The way it deals with the issue of lack of relevance is later discussed. The instrument has been implemented for the last five years in the Faculty of Health Sciences, Ben-Gurion University of the Negev, Israel (BGU), as a sub-test of the summative examination taken by first year students in a six year curriculum.

BACKGROUND

The hereby presented instrument entitled "Hypothetic Organism Test" (HOT) and nicknamed "The Monster" should be viewed against the background of the first year curriculum. A detailed description of the BGU curriculum is available elsewhere (Segall et al, 1978), as is its integrative nature (Benor et al, 1979). Therefore only the content area related to the test will be briefly sketched. However, the objectives of the test reach beyond its actual contents, and are pertinent to the other constituents of both the concurrent integrative curriculum and to later phases of the course.

The science component of the first year program is presented in an integrative format along organ system lines. The multiple solutions found in nature to problems of survival form a background against which the human solution is considered. Human physiology and ecology are studied within a wider biological perspective. The concept of the basic needs of a living organism are raised, such as nutrition, energy production and preservation, and coordination. Pertinent zoological examples are presented in this context. Systematic zoology is not studied, nor are morphological details emphasized. The course is taught on a phenomenological level, and thus stress the observable phenomena and the underlying principles rather than mechanisms and detailed explanations. Appropriate components of physics, mathematics and chemistry are tightly interwoven into the course.

The clinical component of the first year program calls upon encountering real patient problems in various clinical settings. While the main objectives of this component are within the realm of human interrelations (Segall et al, 1978), the student is also expected to apply the knowledge and skills acquired in the science courses to clinical reality as well as to public health issues. An extensive formative evaluation scheme is conducted throughout the year along both disciplinary and interdisciplinary lines. The summative evaluation is based on a single both comprehensive and integrative examination at the end of the year. It comprises several subtests, some of which are case histories. Both scientific and clinical knowledge is objectively evaluated in conjunction with these presented cases. Another subtest is the HOT.

THE INSTRUMENT

The examinee is required to 'construct' a hypothetical creature that should fit given environmental conditions specified in the introductory narrative. The environment may be either real (e.g., desert, tropic island, marine), or imaginary (e.g., high seas after a nuclear disaster which has changed the water's characteristics). Only one environment is designed for each test. A data list provides both pertinent and irrelevant information about the environment (e.g., climate, altitude, chemicals in the water, food supply); and about some behaviors of the creature to be designed (e.g., "dominant", was found both in the mountain area and on the sea shore).

Thirty 'building blocks' are presented, formulated in a multiple option format, from which the examinee is instructed to select one option. Each 'block' relates to either structure, substance or process in one of the organisms body systems. Table 1 presents some examples of 'building blocks'. Table 2 provides additional details relinquishing the multiple option format for convenience of presentation.

Insert Tables 1 and 2 here.

Additional blocks deal with perception and neural mechanisms, excretion, eating, drinking and hunting behavior, regulation of blood pressure, etc. The building blocks are presented at a random order. Thus for example, the eating behavior, structure of intestine, digestive enzymes, water metabolism and tonicity of the extracellular fluid, are blocks numbers 19, 28, 21, 3 and 7 respectively. In addition one open-ended question enables the student to describe the constructed creature.

The examinee is instructed to make his or her choices in a way that the constructed systems as defined by the chosen options would not contradict each other. Moreover, the organism should fit the given environmental conditions. This includes, of course, the open-ended description. The students are encouraged to use their imaginations freely. In order to minimize the tendency toward selecting the options characteristic to human beings, best known to the students, some of the blocks do not include the human solution (e.g., iron is not included among the options of the respiratory pigment block). The student is thus requested to act better than nature did, and to constitute an ideal non-human organism. Students are, of course, unable to do this, and inevitably run into contradiction. A perfect performance is thus defined as having not more than one contradiction.

SCORING

Flow charts are designed as, for example, those described above related to alimentation. The student's choices are checked against lists of both non-permitted and required responses. For example, choosing the option of "acting only in the day time" (block 1) excludes both the option of "constant body temperature at 38 - 40 centigrades" (block 4) as the given environment is cold at night, and also the option "most of visual receptors are rods" (block 17). But it requires one of the thermal protection structures such as fur, feathers or fat (block 10). Each block can be enclosed in more than one flow chart. Each response may be in accord with others in a certain flow chart, yet should not contradict a response in another chart.

The student is penalized for each contradiction. The final negative scores are transformed to standard scores with no more than six contradictions, including the permitted one, being allowed to the minimally performing student. The originality of the student's solutions is assessed by two scorers, and these points are added to the student's credit, contributing up to 10 per cent of the final score. A response is considered original insofar as the solution deviates from a description of a human being. A walking fish, if meeting the environmental conditions, is superior to a cat.

VALIDATION

The face validity of the test is not at all obvious. Although the content is directly derived from the learned subject matter, the task, however, is of a unique nature, never encountered before by any examinee. Because of this uncertainty, the test was regarded as largely experimental until validation.

The establishment of construct validity (Cronbach & Meehl, 1967) was two-fold. Discriminant validity was determined by correlating the HOT scores with those obtained over the different questions in the other sub-test of the some examination, dealing with biological and related scientific material. The results show a low and non-significant correlation coefficient of .06 (table 3), indicating that HOT measured a quality which is independent of the related factual knowledge, in spite of the fact that a considerable proportion of the knowledge questions in those other sub tests were on a high cognitive level.

The convergent validation of the test had to be postponed for four years, until assessment of the clinical performance of the first classes who took the HOT became available. It then was possible to see its correlation with achievements on the familiar branching patient management problems (PMPs), taken within the framework of the obstetrics- gynecology, pediatrics and primary care clerkships (years 4 & 5). A moderate yet significant correlation of .26 ($p < .05$) was found. A higher correlation of .37 ($p < .05$) was found with PMP in internal medicine final examination (year 6). Moreover, an unplanned occasion occurred, in which a PMP in the primary care clerkship was annulled by the teachers because it dealt with a rare and unfamiliar condition. This PMP required application of problem solving skills to an unrecognized, 'theoretical' situation. The correlation with the HOT taken by the same students four years earlier was .43 ($p < .01$) (table 3). These correlations may be seem quite moderate, accounting for not more than 20 percent of the variance in the later years. However, they indicate better predictivity than is usually obtained by tests in medical education. Indeed, higher correlations may question any possible effect of education over the years.

The HOT is a monotrait test. Thus a construct validation by the multitrait-multimethod matrix (Campbell & Fiske, 1959) is impossible. However, HOT is just a one subtest of seven in the first year Integrative Examination, which is a multitrait test. Similarly the PMP is but a subtest in the evaluation of students' clinical performance in the later years. When the multitrait-multimethod model is applied to both the early and the clinical evaluation instruments, an additional construct validation emerges indicated by the 'validity diagonal' (table 3).

insert Table 3 about here

Several additional null hypotheses were ruled out: The score in HOT does not correlate with the admission interview ratings; with the subjective ratings by clinical instructors; nor with intelligence, as measured by Raven's non-verbal intelligence test prior to admission (table 4).

insert Table 4 about here.

DISCUSSION

There is no doubt that medical practice requires appropriate data collection, organization and interpretation. There is also a growing acknowledgement that medicine likewise requires creative thinking, reflected by the hypothesis generation phase of clinical inquiry (Elstein et al, 1978; Culter, 1979). And, further, there is considerable dissatisfaction with medical education, expressed in several rather critical recent articles (e.g., Maddison, 1978) in regard to the acquisition of problem-solving capabilities. However, there is no consensus on the nature of the defficiencies demonstrated by medical students. While some authors focus on cue acquisition capabilities (Berner & Tremonti, 1977), others have found that the fault is lack in the ability to generate hypothesis early enough (Neufeld, 1977; Dornhorst & Hunter, 1967). Resolution of this debate has a meaningful bearing on the planning of new instructional experiences or changing the existing ones. Such resolution requires measuring instruments. It is suggested that the 'hypothetical simulation' approach presented above may serve this end.

The main feature of the test is that there is no ultimate truth. No hidden reality should be discovered; no actual existence influences the flow of events. Moreover, there are no data to be collected, drawn, accumulated or exposed; the data are explicitly given. The student may choose any set of data to comprise a unique universe of his own, into which the solution should fit. The mental process required here is a partial revision of Elstein's clinical inquiry approach. It starts with an interpretation of the given cues on a rather low cognitive level. Then it calls upon extensive hypotheses generation, while selecting the options out of the many offered. The questions that the examinee faces is "which cues should be selected in order to fit the hypothesis best" rather than "which hypothesis fits the facts".

The most important advantage of the test presented here is the preclusion of any 'pattern recognition' shortcut. Under no circumstances can an examinee bypass the hypothesis generation stage and evoke a reflexive response to a familiar situation. As both the interpretation and the selection of the presented options are relatively simple and require a low level of cognition, it is suggested that HOT goes a long way towards focusing exclusively on the hypothesis-generation process.

The construct validity of HOT, both convergent and discriminant, points to some similarities with the PMP, which are larger in the case of a previously unrecognized problem. The results also demonstrate a fundamental divergence from the "knowledge" component. This may shed some light on the argument about content dependency of PMPs (Robinson & Dinham, 1977). The possibility that content-dependency merely reflects pattern recognition must be considered. It is demonstrated that there is no correlation with 'knowing' the content area insofar as the pattern cannot be recognized.

The criterion validation of HOT is beyond the scope of the present communication, and should await additional research data. However, it is assumed that HOT will be found to have criterion validity as high or as low as the PMP. This question is still debatable (Goran et al, 1973), in spite of the high face validity of the 'realistic simulations'.

The issues of relevance vs. student motivation is also further illuminated. Students never rejected the HOT on the grounds of irrelevance. Their motivation level was, and still is high in spite (or because?) of the unrealistic situation. This observation is in accord wih Bruner's postulate (Moore & Anderson, 1969) that there is "... joy and confidence in the use of the mind" expressed by others as an "intrinsic reward value" of problem-solving (Barrows & Mitchell, 1975). It should be very clearly stated that the authors do not suggest a replacement of PMPs and other clinically relevant techniques used in evaluation, but rather to supplement them, without being overly concerned by the reflection of reality issue.

It is interesting to follow the creative process of the students by monitoring their decision on the unavoidable contradiction. There are examinees who try hard to readjust their hypotheses over and over again in order to avoid contradiction. There are others who deliberately introduce the contradiction early in order to enable an easier flow thereafter. Still others encounter the difficulty late, only to find that their entire solution is erroneous. Some students are 'systematic thinkers' and identify our scoring flow-charts intuitively. Others are not aware of the ties between certain blocks, scrutinizing each block against their hypothesis instead of forming clusters of blocks to be checked together. Although no quantitative data are available, this observation supports a recently published assumption on the existence of cognitive styles (Tamir et al, 1979), which were defined as the recall, principled, questioning and application approaches.

The HOT scoring system laid relatively considerable weight on originality of the solution (10%). This reflects an attempt to reward inductive thinking, on the verge of guessing. It has been stated that guessing, or 'wild imagination' is required for creating a clarifying environment. It has been also shown that creativity is correlated with the ability to arouse new associations, detached from the trigger stimulus (a 'chain' pattern) (Levin, 1973). Nevertheless, we must admit that summative evaluation is not the most appropriate situation for assessing the creative imagination, unless this is an explicit objective of the evaluation.

The content areas of HOT are well-nigh unlimited and depend entirely on the available resource people. The test can be easily applied to any phase in the course of studies. (Indeed it may be applied long before the university level). A case in whioh life in space where proteins do not exist (a sort of "Andromeda seed") is one extreme example derived from a cellular rather than organ biology. Solution for a non-existing inborn error of protein metabolism is another example, derived from the same content area. As the findings support the assumption of but a loose content dependency, the actual problem presented is of secondary importance. Alterations are also possible in the entire scoring system, including the assessment of originality. It also may be useful to further develop mechanized scoring. Thus the HOT represents an example of the idea of detachment from reality in order to measure intermediate stages of problem-solving, rather than a structured instrument.

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TABLE 1

Examples of 'Building Blocks'
(numbered according to original sequence in 1979 examination).

1. The animal's body temperature is:

   a. Varies in accordance with environmental conditions.
   b. Constant at values of 36-38°C
   c. Constant at values of between 20-30°C at night and 36-38°C during the day.
   d. Constant at values of between 35-40°C at night and 10-20°C during the day.

7. The ionic composition of the extracellular fluid of the animal in relation to the environment is:

   a. isotonic
   b. hypotonic
   c. hypertonic
   d. varies with food and liquids absorbed

8. The animal muscles are:

   a. a large mass relative to body weight
   b. a small mass, most of which are smooth, and a minority striated.
   c. a large mass, most of which are trunk muscles, and a minority limb muscles.
   d. a large mass mostly in the limbs.

22. The animals major mechanism for reaction speed is:

   a. decreasing cortical inhibition on relexes
   b. increasing cortical control of reflexes
   c. increasing sensitivity to peripheral sensory stimuli
   d. the motor system is under sub-cortical control (extra-pyramidal)

27. The mechanism of regulation of the animal's heart rate is:

   a. Self-regulation by means of a pacemaker in the heart (or each of the hearts) without a central control
   b. central regulation without pacemaker(s)
   c. regulation of the flow by change in peripheral resistance without pacemaker(s)
   d. the animal has no heart at all.

TABLE 2
Additional Summarized 'building blocks'

The item	Summarized examples of the available options
* Weight and Metabolic rate	Several combinations of weight and O_2 consumption
* Breathing apparatus	Several combinations of rate of gas exhange and depth of cavities.
* Respiratory pigments	Several metals with different affinity to oxygen.
* Movement	Alertness and activity; sleeping habits; posture; locomotion.
* Intestine	Number and length of Segments; pH in each.
* Alimentary enzymes	Several combinations of enzymes
* Temperature regulation	Constituents of integument.

One of the options is that the structure under discussion does not exist at all in the organism.

Table 3

Mulitrait - multimethod correlation matrix

of early vs. clinical evaluations (N = 66)

Method	Trait	Integrative Examination (year 1) Problem-Solving HOT	Knowledge of content MCQ*	Interpersonal skills COMMUN. TEST**	Clinical Evaluation (years 4-6) Problem-Solving PMP	Knowledge of content MCQ***	Interpersonal skills RATINGS****
Integrative Examination	Problem-Solving (HOT)	-					
	Knowledge of content (MCQ)	.06	.78				
	Interpersonal skills (COMM.)	.23	.00	-			
Clinical Evaluation	Problem-solving (PMP)	.33+	.22	.04	.21		
	Knowledge of content (MCQ)	.05	.46+	-.11	.34	.43	
	Interpersonal skills (RATINGS)	-.03	.10	.13+	.46	.31	.68

* Over other subtests of the same examination relating to the same content area as HOT
** Another subtest of the Integrative Examination, measuring Communication skills (written test)
*** Over End-of-Clerkships MCQ tests
**** Faculty Ratings on a checklist specifying behaviors

TABLE 4

Correlations Between HOT and both Student's Achievements and Admission Criteria

Source	No. of Students*	Correlation Coefficient**
Admission Criteria:		
Intelligence	192	.07
Interviews Score	192	.00
Achievements:		
Scores in other subtests of same examination (1st year)	192	.06
Mean Scores on PMP's in pediatrics, ob-gyn and primary care (4th, 5th and 6th years)	66	.26+
Score on PMPs, medicine, final (6th year)	30	.37+
Score on PMP of a rare case, primary care (5th Year)	30	.43++
Assessment by clinical instructors over clerkships (4th, 5th and 6th years)	66	-.20

* The different N's represent the number of classes which reached each phase.

** Pearson's Product Moment correlation coefficient

+ $P < .05$

++ $P < .01$