Investigating Diagnostic Problem Solving in Medicine through Cognitive Analysis of Clinical Discourse

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Abstract. Diagnostic problem solving in medicine was investigated through cognitive analysis of discourse in clinical situations: clinical encounters of physicians with a standardized patient (SP); written notes summarizing the subjective and objective clinical observations, differential diagnosis, and treatment plan (including orders for lab or other tests); and debriefing sessions involving review of the differential diagnosis and modification of the diagnosis based on examination of the lab results. Analysis of this corpus reveals how the discourse content and structure reflect competency in: use of a differential diagnosis schema, diagnostic reasoning, construction of causal models to explain case evidence, and interaction with the SP.

Introduction

The knowledge and cognition that underlie competency and expert performance in complex professional domains such as clinical problem solving in medicine are very hard to specify. This is due both to the complexity of the knowledge and cognitive processes that are involved in these domains, and to the difficulty of obtaining and analyzing data that reflect expert performance of challenging tasks in authentic situations and settings. Many studies have established general characteristics that distinguish expert problem solving and reasoning from that of novices (Chi, Glaser & Farr, 1988; Ericsson & Smith, 1991; Ericsson, 1996; Alexander, P.A., 2003). There is by now a large research literature focusing on clinical reasoning in medicine (Barrows & Feltovitch, 1987; Elstein & Schwarz, 2002; Groen & Patel, 1988; Patel & Groen, 1986, 1991, 1992; Schmidt, Norman, & Boshnizen, 1990). Research on diagnostic expertise in medicine has established that experts performing diagnostic reasoning tasks use scripts or schemas to guide the diagnostic process. Experts possess a vast store of diagnostic and biomedical knowledge, and an ability to apply this knowledge using mechanisms of: pattern-matching; backward reasoning to infer causes or diagnostic explanations given patterns of clinical evidence; and forward reasoning (from diagnostic hypotheses to clinical evidence) to evaluate alternative diagnostic hypotheses as explanations of the clinical observations. Experts use their biomedical and clinical knowledge and experience to solve routine diagnostic problems faster than novices, and to reason deeply in solving diagnostic problems that are non-routine or particularly complex.

Most studies of processes of clinical reasoning have used controlled "laboratory" tasks to study diagnostic reasoning. However, the processes involved in clinical competency are much broader than those reflected in these tasks. Clinical expertise involves a broad spectrum of competencies including: (a) conducting the clinical interview (to develop a representation of the

clinical situation and generate initial diagnostic hypotheses based on subjective and objective information elicited from the patient and on the physical examination); (b) the production of a differential diagnosis for a case; (c) ordering appropriate follow-up lab tests and other procedures; (d) developing and implementing a treatment plan; and (e) monitoring and managing the patient's course of treatment. Studies of clinical expertise will require research approaches that can confront the full range and complexity of processes that enable effective functioning in authentic situations of medical practice (Patel, Kaufman, & Magder, 1996). These processes will require analyzing the interactive discourse that occurs with patients (during the patient interview) and with other medical professionals (including consultations with other physicians) throughout the diagnosis and treatment of a patient, and written reports and notes that are produced in treating a clinical case.

We will refer to such discourse as "clinical discourse". The analysis of clinical discourse will have to be able to show how experts' knowledge, comprehension, reasoning, problem solving, and other cognitive processes are reflected in the content and organization of their discourse in authentic contexts of practice in clinical and professional situations. It will also have to analyze how experts' engage effectively in situations of interactive clinical discourse, and how their communicative competency enables them to function effectively as medical experts within these clinical and professional situations. In medicine the lack of an adequate model of professional competency, that embodies both a cognitive and a social perspective, is a serious obstacle to specifying and assessing clinical competency (Kelson, 2000).

The types of situations in which clinical competency in medicine can be observed in practice include: (a) the physician-patient encounter; (b) the preparation of formal case reports following a diagnostic encounter (called "SOAP Notes" for Subjective and Objective Assessment and Plan); (c) the discussion of a clinical case with other professionals to review the current differential diagnosis and treatment plan; and (d) the evaluation of laboratory results and other new clinical information to revise the differential diagnosis to accommodate the new evidence. Data from these types of situations can provide a basis for developing models of experts' clinical competency, and to investigate the development of competency in medical students and during medical residency.

Therefore, a good place to start is to collect samples of the discourse (including written SOAP notes) and clinical problem solving of experienced physicians within these types of authentic clinical situations. Using dialogue in a problem-based learning group in medicine as an example, Koschmann (2000) and Evensen & Koschmann (2000) have argued that the analysis of such discourse can reveal the learning and cognition that occur in such groups and that such an analysis requires the use of approaches from multiple disciplines. In this paper we describe an approach that focuses on analyzing the semantic content and the conversational structure of clinical discourse, and how the discourse content and structure reflect the physician's declarative and procedural knowledge, reasoning, and application of problem-solving methods. The results that will be presented here focus on demonstrating how a cognitive and interactive sociolinguistic approach to the analysis of clinical discourse can contribute to the problem of modeling knowledge and clinical competency in medicine.

The Corpus of Clinical Discourse

In an effort to develop a more adequate specification of clinical competency in medicine, a multidisciplinary research consortium has been organized at the Southern Illinois University School of Medicine to undertake a large-scale project focused on investigating cognitive and interactive processes in clinical problem-solving situations. The data for the project will consist of videotaped discourse and written text obtained in the following situations: (a) a clinical encounter with a single standardized patient (SP) in an examining room setting, (b) a written SOAP note

produced at a computer immediately following the clinical encounter, and (c) a debriefing session with a professional in which the SOAP note is discussed, results of lab tests are presented, and the differential diagnosis is reviewed and revised to accommodate the lab test results. The SP is an experienced female actor who plays the role of a real patient in a case work-up developed by a team of physicians on the basis of a real and challenging clinical case. The discourse recorded in these videotaped situations provides the primary data for investigating diagnostic competency in clinical situations.

This paper reports the results of a discourse analysis of preliminary data obtained using a single SP and diagnostic problem (a case of *polycythemia vera*, a bone marrow disorder causing a overproduction of red blood cells). Results are presented for three subjects that were selected from a larger sample of participants: (1) an experienced physician (a faculty member), (2) a second-year medical student, and (3) a third-year medical resident.

The clinical discourse produced by the subjects in each of the above situations was analyzed to explore: (a) how a differential diagnosis schema organizes the clinical problem-solving and the episodic structure of the discourse; (b) the construction of a representation and interpretation of the clinical case evidence through interaction with the SP in the clinical interview; (c) the development and evaluation of a list of alternative diagnostic hypotheses in producing a differential diagnosis and treatment plan; and (d) the use of causal models of the sequence of processes that are involved in the production of red blood cells to understand and reason about the case. We examined the subjects' knowledge and use of three causal models that are applicable to understanding this case: models of red blood cell production in patients with *polycythemia vera*, patients with anemia, or patients having normal production of red blood cells. The analysis of the physician's dialogue with the SP focused on examining how the cognitive processes and knowledge involved in clinical problem solving were reflected in the clinical encounter with the patient.

We began by developing an "expert model" based on the analysis of a "Gold Standard" SOAP Note produced by an expert physician. This SOAP Note consisted of the SOAP Note written after the clinical encounter with the patient, and two additions: first, the results of the lab tests requested by the attending physician; and second, a revised assessment of the case and treatment plan based on the results of the lab test. This expert model was applied to analyze the clinical discourse and problem solving of the experienced physician. The model was revised based on these results. The resulting revised model was reviewed by the experienced physician. This revised model was used subsequently as a template for analyzing the discourse and problem solving of the medical student and the resident to examine how individuals at different levels of medical training and experience differ from the experienced physician.

The results presented in this paper are intended to illustrate the clinical discourse that was obtained in the research, describe the application of cognitive discourse analysis methods to clinical discourse, and illustrate the results that are obtained using this methodology, including a demonstration of how they reflect differences in the training and experience of the subjects. The results should be regarded as specific to the subjects studied and specific clinical case used in the collection of the data. Any general conclusions about the processes and knowledge underlying expertise in diagnostic problem solving in medicine, and their development as a function of training and experience, will depend on results obtained after the cognitive discourse analysis methodology has been applied to the entire corpus of clinical discourse collected in this research, and to data obtained using additional diagnostic problems.

Cognitive Analysis of Clinical Discourse

The approach to the analysis of the clinical discourse is similar to that reported in the analysis of an excerpt of dialogue in which a clinical case was discussed in a PBL group in medicine

(Frederiksen, 1999). The method of cognitive discourse analysis also has been applied in research on expert tutoring in engineering and statistics (Frederiksen, Donin, & Roy, 2000; Frederiksen, Roy, & Bédard, 2005; Frederiksen & Donin, 2005).

The present analysis begins first with an analysis of the procedures that are used to solve diagnostic problems. The result of this analysis is a model of the "differential diagnosis schema" that is used by the physician to guide the clinical problem solving process. This schema model is developed through a cognitive task analysis and procedural frame analysis of the interactive discourse produced in the clinical situations, viewed as a task-oriented dialogue, and including any written discourse produced in solving the diagnostic problem (i.e., the SOAP note and orders for lab tests). The differential diagnosis schema represents the physician's knowledge of problem-solving methods that are being applied to understand and diagnose the case. Second, an analysis of the semantic (i.e., propositional) content of the discourse is carried out to develop models of: (a) the cognitive representations that are being constructed for the case (e.g., "causal models of the case"), and (b) the reasoning processes that are reflected both in developing alternative causal explanations of the case evidence and in evaluating the relative likelihood of each causal hypotheses as a valid diagnostic explanation of the case.

The following results will be presented to illustrate how cognitive analysis of clinical discourse collected in simulations of authentic clinical situations can be used to develop models of cognitive aspects of clinical competency:

1. An "expert" *differential diagnosis schema* based on the analysis of an experienced physician's SOAP note and the debriefing dialogue, and results based on applying the differential diagnosis schema to analyze the problem solving activity of a second-year medical student, and a third-year resident, based on their SOAP notes and debriefing dialogues.
2. Analysis of the construction of a case representation based on dialogue interaction with the SP in the situation of the patient examination. This includes the collection of case data and generation of hypotheses in the situation of the clinical encounter. It also includes comparison of the experienced physician to the medical student and to the resident.
3. Analysis of the processes involved in generating and evaluating diagnostic hypotheses to construct a differential diagnosis for the case, including *diagnostic reasoning* processes. Results will be presented comparing the experienced physician's reasoning to that of the medical student and the resident as reflected in the SOAP Note and dialogue in the debriefing interview.
4. Analysis of the SOAP note and discourse of the experienced physician to investigate their *causal models of the case*, and a comparison of the "expert" causal models they construct to causal models constructed by the student and the resident.

We will discuss these preliminary results from the standpoint of how a cognitive approach to discourse analysis can contribute a methodology for modeling and assessing competency in the complex social and cognitive processes that are required by clinical and professional situations in medical practice. We emphasize how "expert models" are constructed based on authentic performance data, how a model can be tested against data from other experts, and how such models can provide templates for assessing the developing competency of students and residents. We also will discuss the need for analyses from multiple perspectives by addressing how a cognitive analysis such as that presented here can complement a conversational analysis of clinical encounters which focuses on the *clinical dialogue* with the patient. Finally, we will comment on discourse communication as an aspect of clinical competency in medicine.

Clinical Discourse as Task-Oriented Discourse

A dialogue that occurs among participants during the performance of a task or activity constitutes a task-oriented dialogue. The conversational structure and the content of the dialogue reflect the participation of the speakers in the common task and the content and communicative functions of their discourse in the context of their shared activity. Clinical discourse is a form of task-oriented discourse for several reasons. First, the clinical discourse is situated in clinical problem-solving situations in medicine. The clinical discourse includes both task-oriented dialogue (e.g., patient interviews, professional discussions of a case), and written text (SOAP Notes). Each is a form of task-oriented discourse, since each form of clinical discourse reflects the situation and activity of clinical problem solving in medicine which constrains the structure and content of the discourse.

The dialogue between a physician and a patient in a clinical situation is clearly task oriented since it reflects both the physician's conduct of the clinical encounter (including the task of developing an initial differential diagnosis) and the patient's participation in the encounter for the purpose of informing the physician about a perceived health problem, its history and presenting symptoms. The successful conduct of this encounter is essential to develop an accurate representation of the subjective and objective information from which to comprehend the clinical situation, conduct an initial diagnostic assessment, construct a differential diagnosis to explain the clinical situation, and produce a follow-up plan.

The SOAP Note is a report that is written immediately after the clinical interview, and that summarizes the diagnostic situation, assessment, and plan developed during the clinical interview. Thus, although it is a written discourse, it can be regarded as a formalized task-oriented discourse that is framed by the "SOAP Note Script". This script mirrors the structure of the differential diagnosis schema that frames the entire clinical problem-solving process.

Finally, the debriefing interview is a form of discourse in a professional situation in which the physician reviews his/her SOAP Note with a "colleague", is presented with lab test results, discusses the interpretation of the lab tests, modifies the differential diagnosis based on the lab test results, and outlines an intended treatment and follow-up plan. The debriefing interview also has aspects of a structured interview as well in which the interviewer probes how the physician evaluated the hypotheses under consideration to come up with a differential diagnosis. However, whether it is construed as a dialogue with a medical professional or with an informed interviewer, the dialogue is focused on the task of arriving at a differential diagnosis and plan for the case.

In all of these instances, the clinical discourse functions as a form of task-oriented discourse, since the discourse reflects the situation and activity of clinical problem solving in medicine which constrains the structure and the content of the discourse.

The Differential Diagnosis Schema

Research on expertise across many domains has indicated that experts are able to perform complex tasks and solve problems by framing their actions through the use of a hierarchically-organized *procedural frame* or *schema*. The solution of complex problems by experts is highly systematic, governed by knowledge of how problems decompose into sub-problems and of the methods that can be used to solve these sub-problems. Schema representations of the structure of problems and of the methods for their solution are accessed in memory and used to control the production of a sequence of problem-solving episodes and actions to produce a solution to a problem. This framing of problem-solving activity can include episodes that require a variety of cognitive processes including comprehension, planning goals and actions, carrying out actions, reasoning and evaluating (Frederiksen & Donin, 2005; Frederiksen, Roy & Bédard, in prep.). Moreover, processes such as comprehension, reasoning, and evaluation often involve the applica-

tion of declarative knowledge that is pertinent at any point in solving a problem or carrying out a complex activity.

In medicine, all of these aspects of knowledge application, problem-solving, and cognitive processes that occur within clinical situations will be reflected in the structure and content of the clinical discourse. Thus, in medicine, clinical problem solving is framed by the physician's knowledge and use of a schema to organize differential diagnosis methods and procedures in the clinical problem-solving situation. This knowledge is represented as a "Differential Diagnosis Schema" that frames the problem-solving activity in clinical situations. Consequently, the use of a differential diagnosis schema will be reflected in the content and organization of the task-oriented discourse that occurs in clinical situations. This procedural schema is an important component of clinical competence in medicine. It is explicitly taught to medical students, and it is reflected formally in the script that organizes the standardized SOAP Note. The production of a written SOAP Note is a required component of clinical practice and always occurs immediately following the clinical interview with the patient. The standardized SOAP Note provides a summary record of the results of the clinical examination and includes the initial differential diagnosis of the case and plan for follow-up tests and treatment.

An example of a SOAP Note written by the experienced physician who prepared the case used in this study is given in Figure 1. We will refer to this SOAP Note as the "Gold Standard" for this case, since it provides an "expert model" of a SOAP Note for the case that was produced based on the clinical examination and interview.

Notice that the SOAP Note in Figure 1 consists of the following sections and sub-sections:

1. CASE NAME: identifies the patient
2. PRESENTING SITUATION: a brief description of the patient and her presenting complaint
3. S. SUBJECTIVE DATA: A summary of the findings based on the interview with the patient organized in terms of the following sub-headings:
    a. History of Present Illness
    b. Past Medical History
    c. Current Medications
    d. Family History
    e. Allergies
    f. Social History
4. O: OBJECTIVE DATA: A summary of the results of the physical exam including the following sub-headings:
    a. Vital Signs
    b. HEENT (head, ears, eyes, nose and throat)
    c. Neck
    d. Lungs
    e. Abdomen
    f. Neurological
    g. Skin
    h. Orthostatics
    i. Extremeties
5. A: ASSESSMENT: A list of diagnostic hypotheses in order of likelihood or importance (the first is the "leading hypothesis")
6. P: PLAN: A summary of the treatment plan and follow-up, and a list of follow-up tests (lab tests or diagnostic procedures) that were requested.

Figure 1 – “Gold Standard” SOAP Note

***CASE NAME: SHIRLEY NAYLOR**

***PRESENTING SITUATION:**

Shirley Naylor is a 35 year old female who presents with a two-day history of headache.

***S. SUBJECTIVE DATA:**

History of Present Illness.

The patient presents with a three-day history of left-sided headache.
She reports seeing "squiggly lines" and one episode of vomiting at the onset of the headache.
She has felt nauseous since that time.
Other than the initial scotoma,
she reports no changes in vision which she describes as "pretty much 20/20."
She had started menses on the first day of this headache
and reports having cleaned the garage (moving boxes, sweeping, etc.) five days prior to presentation.
She has been taking Advil since the onset of this headache,
but with little relief.
On reflection she reports having awakened daily with a headache "in the back of my head" since then.
This is in addition to the unilateral headache which has brought her in.
Associated symptoms include fatigue, dizziness and lightheadedness worsening over the past month.
The dizziness and lightheadedness are worsened by postural changes such as bending to pick something up.
She reports that her skin "feels itchy" particularly after a hot bath or on exertion
The patient reports that her “legs and feet fall asleep when she’s on the stool” for about the past month.
She denies nasal congestion, weakness, numbness, chest pain, shortness of breath, weight loss or fever and sleep disturbances.

Past Medical History.

Positive for asthma, controlled with an albuterol inhaler prn,
and irritable bowel syndrome, controlled with fiber intake (Metamucil).
The patient experienced an episode of stress-related depression five months ago for which she was treated with Celexa which she discontinued on her own after two months.

Figure 1– "Gold Standard" SOAP Note (cont.)

Current Medications.

Patient is currently on an albuterol inhaler prn .
She has been taking Advil since the onset of the left temporal headache, but with little relief.

Family History.

Father has a history of asthma.
Mother has a history of rheumatoid arthritis.

Allergies.

No known allergies

Social History.

Patient denies smoking, ETOH use or drug use.
She has been married for five years.
Her husband is supportive.
She has two children from a previous marriage.

***O. OBJECTIVE DATA:**

Vital Signs.
Weight:WNL,
BP: 112/58
Height: WNL,
Pulse: 72
Temp: 97.1,
Resp: 12
HEENT: Negative
Neck: Supple, no lymphadenopathy, thyromegaly or carotid bruits.
No tenderness on palpation of temporal arteries.
CV: RRR without murmurs, gallops or rubs.
Patient reports a mild feeling of dizziness
when asked to bend forward to touch her toes.

Figure 1– "Gold Standard" SOAP Note (cont.)

Lungs: Clear to auscultation.
Abdomen: No hepatosplenomegaly, masses or tenderness.
Extremities: No edema, pulses strong and symmetric;
Deep tendon reflexes and strength within normal limits.
Neurological: Alert and oriented X 3.
Neuro exam within normal limits.
Skin: Clear, no rashes, dryness or jaundice

***A. ASSESSMENT**

Headache with migrainous and tension components.
Fatigue
Lightheadedness
Hx of Asthma
Hx of IBS
Hx of Depression

***P. PLAN**

Symptomatic treatment (NSAID) of headache with close follow-up
CBC,
TSH.
Laboratory Follow-up.
Received the next day.
Patient notified by phone.
Headache is improving.

The SOAP Note presented in Figure 1 is a written record of the results of the interview with the patient and the physical exam. The transcripts of the clinical discourse obtained during the SP encounters will reflect the activity of obtaining subjective and objective data in the situation consisting of the clinical encounter with the SP in the examination room (which was videotaped). Consequently, the standard organization of the SOAP note reflects aspects of the differential diagnosis schema related to collecting evidence from the SP encounter, developing a differential diagnosis, and planning follow-up tests and treatment. Moreover, the content of the SOAP Note sub-headings summarizes the content of the dialogue with the SP in the clinical situation. Therefore, analysis of the SP encounter dialogue and the SOAP Note discourse in our corpus will provide converging evidence for investigating the structure of an expert differential diagnosis schema, how it is applied in the SP encounter, and how the results of the encounter are summarized in the SOAP Note.

The "Gold Standard" SOAP Note includes, following the PLAN section, an Addition that was written after the lab results were received (Figure 2). The additions to the SOAP Note include:

1. The results of the lab tests (these are normally available in a computer output);
2. A: ASSESSMENT: A revised assessment of the case, i.e., a revised list of diagnostic hypotheses;
3. P: PLAN: A revised plan for additional follow-up tests, consultations with medical experts, and treatment.

Figure 2 – Additions to the "Gold Standard" SOAP Note – Laboratory Data

*Laboratory Data

CBC and Differential:
WBC Count 10.57
RBC Count *6.68
Hemoglobin *19.5
Hematocrit *58.4
MCV 87.4
MCH 29.2
MCHC 33.4
RDW *15.6
Platelet Count *540
MPV 9.8
ABS Total Neuts 6.48
ABS Lymphocytes 2.68
ABS Monocytes 0.53
ABS Eosinophils *0.82
ABS Basophils 0.06

Peripheral Blood Smear:
Thyroid Stimulating Hormone (TSH) 1.70
Arterial Blood Gases
Blood PH 7.44
PCO2 *32.3 MM HG (L)
CO2 CNT. 23.3 MMOL/L
Bicarb 22.3 MMOL/L
PO2 129 MM HG (H)
O2 SAT 99.0% (H)
%O2 Hgb NP
Base Excess 0.0
O2 Admin. 21%
B12 levels 704 pg/ml

Figure 2 – Additions to the "Gold Standard" SOAP Note – Assessment and Plan

***A. ASSESSMENT**

Polycythemia
History Asthma
History Irritable Bowel Syndrome
History Depression

***P. PLAN**

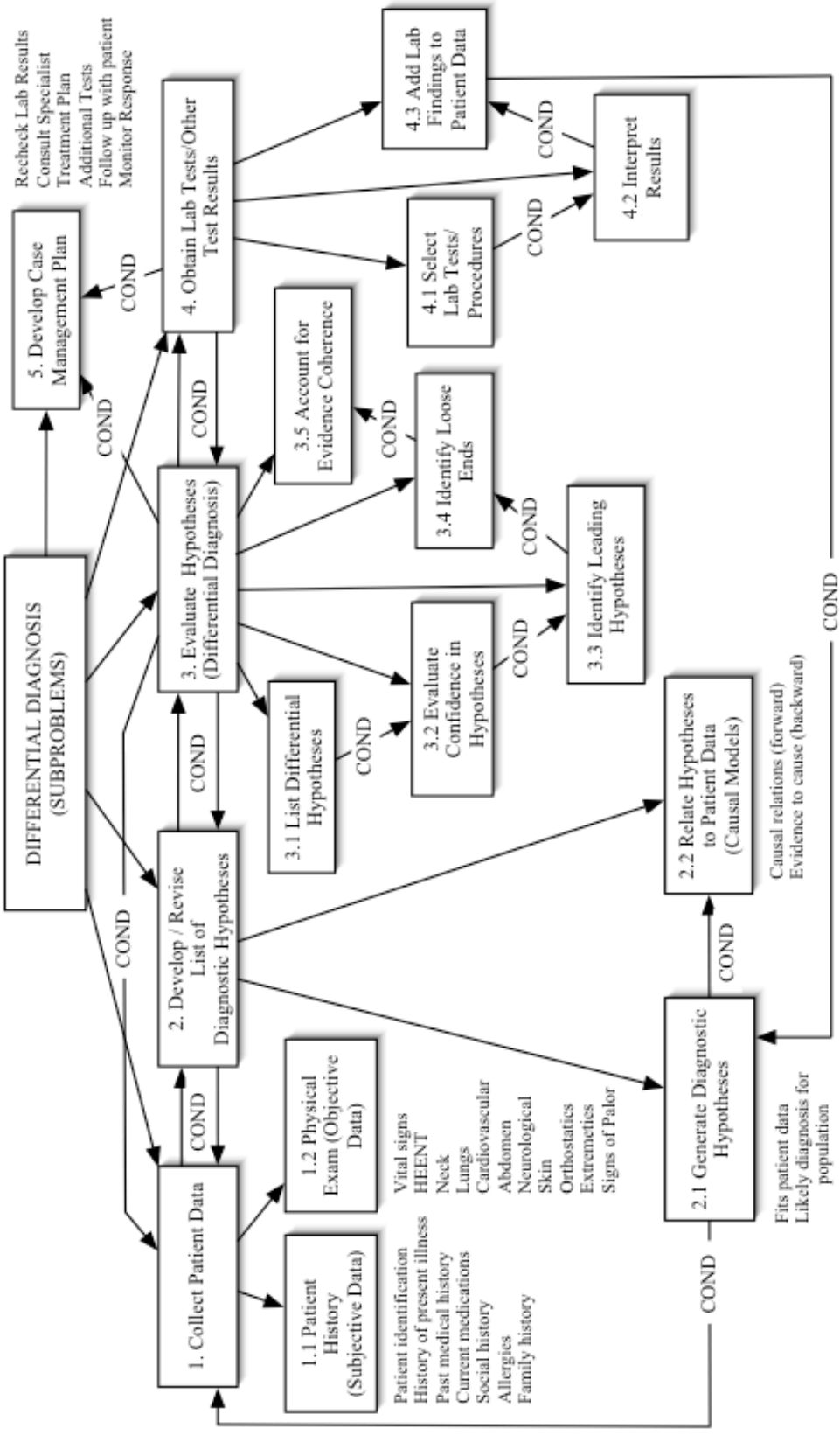
Recheck CBC, Peripheral Smear, ABG, B12 binding capacity.
Phone consult urgently with hematologist.
Send to Transfusion Medicine for Phlebotomy, 500cc.
Blood replaced with normal saline
(As per phone consult with hematologist.)
Refer to hematologist for evaluation and probable bone marrow biopsy.

Inspection of the new ASSESSMENT (given in the additions to the SOAP Note) reveals that the differential diagnosis has been revised from that produced in the initial assessment. The PLAN section also has been revised to reflect the changed differential diagnosis of the case. The production of these revisions to the original SOAP Note would have to be explained by this expert physician's ability to interpret the lab test results, identify the "signature" for a particular disorder (*polycythemia vera*) in the lab test results based on his prior biomedical and clinical knowledge, and apply his experience with similar cases and his knowledge of how to treat this rare and serious blood disorder to produce the revised Assessment and Plan.

The corpus of clinical discourse in the present study affords an opportunity to investigate the process of revising a differential diagnosis and treatment plan on the basis of lab test results for this clinical case. Analysis of the clinical discourse produced during the "debriefing interview" will enable such an investigation of the knowledge, clinical reasoning and expertise of experienced physicians, medical students, and residents. The debriefing interview begins with a review of the "thinking" and reasoning underlying the Assessment and Plan given in the SOAP Note prepared by the subject (an experienced physician, medical student, or resident). This constitutes a kind of "retrospective protocol" covering the process of evaluating the clinical evidence, identifying possible diagnostic hypotheses as explanations of the clinical evidence, and evaluating alternative hypotheses to establish a differential diagnosis and leading hypothesis. Then, the subject is presented with the lab results, and proceeds to interpret them through dialogue interaction with the interviewer. The subsequent dialogue reflects the process of arriving at a new assessment (differential diagnosis) and plan for treatment and additional follow-up tests to confirm the leading diagnosis.

A model of the differential diagnosis schema was developed on the basis of a discourse analysis of: (a) the Gold Standard SOAP Note; and (b) the SP encounter, SOAP Note, and Debriefing Interview obtained from one of the faculty members participating in the study (an experienced physician). The schema model was reviewed by the experienced physician whose data were used to develop the model. Such a review by expert participants in the study is a feature of our methodology. The differential diagnosis schema model is given in Figure 3.

Figure 3 – The Differential Diagnosis Schema



A problem schema model consists of *nodes* that represent procedures, hierarchical *links* that relate a procedure to its sub-procedures (i.e., that specify its *decomposition* into sub-procedures), and links that connect a procedure to alternative *disjunctive* choices of sub-procedures (corresponding to alternative methods for achieving the goal of the parent procedure). Procedures within a decomposition subtree (i.e., that represent the components of the parent procedure node) may be connected sequentially in terms of *conditional* (i.e., a COND relation) or *temporal order* (i.e., an ORD-TEM relation) constraints on their order of execution. Disjunctive procedures are connected by an "alternative or" (i.e., an OR) relation.

It can be seen in Figure 3 that the differential diagnosis schema includes five main components:

1. Collecting and interpreting data in the clinical interview
2. Developing a list of diagnostic hypotheses (the "differential")
3. Evaluating the differential hypotheses, selecting a leading hypothesis, and identifying "loose ends"
4. Ordering laboratory tests, interpreting their results, and revising the differential diagnosis
5. Developing a case management plan based on the differential diagnosis

These component sub-problems of the differential diagnosis method (as identified in the schema) are linked by conditional relations. Thus, (1) collecting evidence (findings) in the SP encounter is a condition for (2) developing a list of diagnostic hypotheses, which is itself a condition for (3) evaluating diagnostic hypotheses (to produce the differential). The evaluation of diagnostic hypotheses (3) is a condition for (1) collecting additional clinical evidence in the SP encounter; and it is also a condition for proceeding to (4) order lab tests and other measures, and (5) proceeding to develop a case management plan. Interpreting the lab tests (or other measures) provides a condition for: (1) collecting additional clinical evidence from the patient; (2.1) identifying possible diagnoses to explain the new evidence; (2.2) linking diagnostic explanations to the evidence (by means of causal models or pathways); and (5) planning how to manage the case. Obtaining new results can lead to revision of the differential diagnosis through re-application of the schema. Once this recursive cycle of evaluating and revising the differential diagnosis is completed, the case management plan (5) can be revised as well. The "Gold Standard" SOAP Note records the results obtained from an expert diagnostician. It represents a model of the schema knowledge that experts apply to collect clinical evidence needed to develop a representation of the clinical situation, generate a differential diagnosis for the case, and develop a treatment plan for the case.

In addition to the physician's knowledge of the differential diagnosis schema (procedural knowledge), our results will show that the content of clinical discourse also reflects the physician's application of declarative clinical and biomedical knowledge including:

1. *Evidence Models* - knowledge of types of subjective and objective data, and of specific lab tests and results;
2. *Clinical Knowledge* - linking causes (disorders) to specific patterns of clinical evidence (symptom patterns);
3. *Causal Models* - of the physiological processes that underlie normal and abnormal biological functions.

Clinical Discourse as a Representation of Clinical Problem Solving

Our objective in this study was to investigate how the analysis of clinical discourse could provide a foundation for developing models of clinical competency that can expand existing

models of clinical reasoning expertise and extend our understanding of the knowledge and processes that constitute clinical expertise to include a broader view of clinical competency. This broadened view of competency includes many of the components of performance that are involved in clinical practice. These components are reflected in the differential diagnosis schema. Our research strategy for developing such a broadened account of clinical competency in medicine was to obtain videotapes of clinical problem-solving activities in authentic situations which simulate a variety of contexts which occur in clinical practice – ranging from the initial patient encounter to the development of a case management plan. To provide a sound methodological framework for the investigation of clinical competency through analysis of clinical discourse in these situations, we need to answer two questions:

How are the knowledge and processes that underlie clinical competency reflected in the structure and organization of clinical discourse?

We will consider this question in terms of how knowledge and processes of clinical problem solving are likely to be reflected in the structure and content of clinical discourse obtained in the present study: the SP encounter, the SOAP Note (including requests for additional tests), and the debriefing interview (including review of the SOAP Note, interpretation of lab test results, and reassessment and revision of the differential diagnosis and case management plan). We hypothesize, and will demonstrate by analysis of data from our corpus, that there are four principal levels of structure and organization of the clinical discourse, and that these reflect four major aspects of clinical competency:

1. *The macrostructure of clinical discourse*. Since clinical discourse functions as task-oriented discourse, the high-level structure and organization of the clinical discourse is framed by the application of the differential diagnosis schema to organize problem-solving activity within the clinical situations we are studying. Consequently, we hypothesize that the differential diagnosis schema functions to frame clinical discourse such that the discourse consists of topical sequences (i.e., stretches of discourse) that correspond to the particular components of the differential diagnosis schema that are being applied. Thus, the topical organization (i.e., the discourse macrostructure) is a reflection of the underlying schema that is being applied to control activity in the clinical situation.
2. *The episodic structure of clinical discourse*. If we assume that clinical problem solving reflects the sequential application of components of a differential diagnosis schema to organize problem-solving activity into a sequence of problem-solving episodes, we would expect the episodic structure of problem solving to be reflected in the episodic structure of the clinical discourse. Consequently, consistent with results obtained from previous studies of one-to-one tutoring by experts (Frederiksen, Donin, & Roy, 2000; Frederiksen, Roy, & Bédard, 2005; Frederiksen & Donin, 2005), we hypothesize that since clinical problem solving consists of a sequence of episodes in which schema components are being applied to organize current activity in solving the problem, the clinical discourse will be organized in terms of an episodic structure that reflects a trace (i.e., a particular order) of procedures from the differential diagnosis schema that are being applied, and this trace will correspond to an orderly and stable sequence. Thus the episodic structure of the discourse reflects the systematic nature of the clinical problem solving activity.
3. *The discourse content as application of declarative knowledge*. Research on expert diagnostic reasoning in medicine has shown that experienced physicians apply their declarative knowledge to a case to generate and evaluate hypotheses. Since clinical discourse is a form of task-oriented discourse, we would expect these processes to be reflected in the propositional (semantic) content of the clinical discourse that occurs within episodes. Within a problem-solving episode, an experienced physician is able to apply appropriate declarative knowledge in the context of a particular component of the problem solving.

For example collecting evidence in the SP encounter depends on knowledge of a large potential array of clinical evidence that may be important to diagnosis of the case. This knowledge of kinds of evidence is vast, and is closely integrated with procedures (1.1) for obtaining the patient history, and (1.2) conducting the physical exam. The physician also applies clinical knowledge of patterns of evidence linked to particular diagnostic explanations to (2) develop and revise a list of diagnostic hypotheses, and (3) evaluate and compare the likelihood of alternative diagnostic hypotheses and develop the differential. Knowledge of lab tests and their significance is important to (4.2) interpreting lab results; and biomedical knowledge of normal and abnormal causal models of physiological processes and their pathologies is important to (2.2) explain evidence, (3.2) evaluate hypotheses, (3.3) select leading hypotheses, (3.4) identify "loose ends" (i.e., evidence not accounted for by the diagnostic hypotheses), and (3.5) account for evidence coherence.

4. *The interactive structure and content of dialogue in clinical contexts*. Interactive clinical contexts such as the initial clinical encounter with the patient are conducted within a context of clinical problem solving. For example, one primary goal of the initial clinical interview (e.g., the SP encounter) with the patient is to collect the clinical evidence needed to understand the clinical situation of the patient and diagnose the case. The clinical dialogue in such situations functions both as a cooperative task-oriented dialogue, and as a goal-oriented interactive task environment. The communicative expertise required involves specialized social communication skills that are adapted to the problem-solving requirements of the situation. Such communicative expertise also is involved in situations of professional communication with colleagues or patients which may occur in relation to any aspect of the clinical problem solving. We expect doctor-patient dialogue in the SP encounters to reflect a specialized adaptation of conversational processes to the particular goals of the clinical situation. Thus, we expect strong interactions between aspects of the conversational structure and content, with the current goals of the clinical situation.

Given the cognitive processes and knowledge that are involved in clinical problem solving (broadly defined), what methods of discourse analysis can be applied to the clinical discourse to investigate these processes in experts, medical students, and residents?

Given the strong relationships between the cognitive and socio-cognitive activities that occur in interactive situations of clinical problem solving, we require a systematic methodology for the analysis of the clinical discourse, both to investigate the cognitive processes and knowledge that constitute clinical competency, and to investigate communicative competency in particular kinds of situations of clinical practice. Our approach to developing a systematic methodology for the analysis of clinical discourse in the present study was to focus on five aspects of the cognitive processes that we hypothesize are involved in clinical problem solving in medicine:

1. *Analyze how the discourse macrostructure reflects a process of applying the differential diagnosis schema*. Units of clinical discourse (dialogue or text units) can be matched to particular nodes in the differential diagnosis schema. Normally, there will be sequences of discourse units that match a particular component of the schema, followed by a shift to another component of the schema, etc. Thus, the discourse is divided into "topical units" that correspond to components of the differential diagnosis schema that are being applied.
2. *Analyze the episodic structure of the discourse*. A sequence of text units that corresponds to a single component of the differential diagnosis schema constitutes an episode. The episodic structure of the discourse reflects a sequence of episode units (chunks of discourse) that correspond to the episodic structure of the problem solving.

3. *Analyze how the dialogue content and structure during the SP encounter reflect the processes involved in collecting and interpreting patient data*. The processes of collecting and interpreting patient data that occur during the SP encounter involve: first, a detailed list of types of patient history information elicited from the SP that constitute the "subjective" data (1.1); and second, a physical exam producing the "objective" data (1.2). It also involves processes of (2.1) identifying possible diagnoses to explain evidence, and (2.2) linking explanations to evidence using causal models. Semantic analysis of the propositional content of the SP encounter, the SOAP Note, and the debriefing interview can be studied as evidence of these processes. The processes involved in interacting with the patient can be studied through analysis of the dialogue structure during the SP encounter.
4. *Analyze how the propositional content of the clinical discourse reflects the cognitive processes of developing and evaluating a list of alternative diagnostic hypotheses, i.e., the development of a differential diagnosis for the case*. This process involves well-defined procedures for: (3.1) reviewing the current list of alternative hypotheses, (3.2) evaluating specific hypotheses, (3.2), selecting a leading hypothesis, (3.3)identifying loose ends, and (3.5) accounting for evidence coherence. These processes will be reflected in the propositional content of discourse episodes associated with these components of the differential diagnosis schema.
5. *Analyze how the propositional content of the clinical discourse reflects the use of causal models to understand and reason about the case*. These processes also will be reflected in the content of discourse associated with particular components of the differential diagnosis schema. Use of causal models to evaluate hypotheses, reason about the case, and explain the case evidence will be reflected particularly in the analysis of conditional and causal propositional structures in episodes of the discourse that: (2.2) explain case evidence, and (3) evaluate or re-evaluate diagnostic hypotheses to produce a differential diagnosis.

Results

Results will be presented pertaining to each of these aspects of the cognitive processes that are involved in clinical problem solving as they are reflected in the structure and content of the clinical discourse.

1. Use of the differential diagnosis schema and the episodic structure of clinical problem solving

We will begin with the first two aspects of clinical discourse raised previously: (a) analyzing how the discourse macrostructure reflects an organization based on the application of the differential diagnosis schema during clinical problem solving; and (b) analyzing the episodic structure of the clinical discourse as a reflection of the systematic organization of problem-solving episodes during clinical problem solving.

The differential diagnosis schema (Figure 3) was initially developed based on the "Gold Standard: SOAP note. It was then applied to analyze the clinical discourse obtained with an experienced physician (a faculty member) during the SP encounter, the SOAP Note, and the debriefing interview. The model was refined and elaborated on the basis of the analyses of these data, and the resulting model was reviewed by the participating faculty member whose discourse protocols were used to revise the model. The revisions consisted of: (a) refining and expanding the decomposition of node 3 (evaluate hypotheses), (b) adding certain conditional links to the schema; (c) elaborating lists of sub-procedures of certain "leaf" nodes in the hierarchy (1.1, 1.2, 2.1, 2.2, 5) to specify a fourth level of sub-procedures for those nodes; and (d) adding specific lab tests to nodes 4.1 and 4.2.

The revised schema (Figure 3) was applied to analyze the clinical discourse of the three subjects (the experienced physician, the medical student, and the resident). The corpus analyzed consisted of nine discourse files: the SP encounter, SOAP note, and debriefing discourse for each of the three subjects. We will use our analysis of the debriefing discourse with the experienced physician to illustrate, first, how the discourse structure reflects the systematic application of the differential diagnosis frame; and second, the episodic structue of the discourse. The entire transcription of the debriefing interview with the experienced physician is given in Appendix A.

A trace analysis of the debriefing interview prior to presentation of the lab test results is given in Figure 4. In this part of the debriefing interview, the subject is reviewing the SOAP note she has previously written for this case (following the clinical interview), and is explaining the basis for her differential diagnosis. The bold face numbers in Figure 4 refer to text units in the transcribed protocol. The letter 'K' following a number indicates that the preceding text unit was produced by the interviewer. By following the text unit numbers, the trace of application of procedures can be seen. In Figure 4, the units from 6 to 41 refer to the subject's description and explanation of her SOAP Note. The sequence in the subject's review of her differential diagnosis was as follows:

1. Collect patient data (6-26)
2. Develop list of hypotheses (28-29)
    a. Generate hypotheses by fitting patient data
3. Evaluate hypotheses (29-31)
    a. List hypotheses
    b. Evaluate confidence in hypotheses
    c. Identify loose ends
4. Develop case management plan (32-36)
5. Identify loose ends (38-39)
6. Obtain lab tests (39-41)

This sequence reflects an orderly application of the differential diagnosis schema, reflecting the conditional links and sub-procedures present in the schema structure. In her discourse, the subject did not explicitly relate hypotheses to the patient data (using causal models), identify leading hypotheses explicitly, or attempt to explicitly account for evidence coherence.

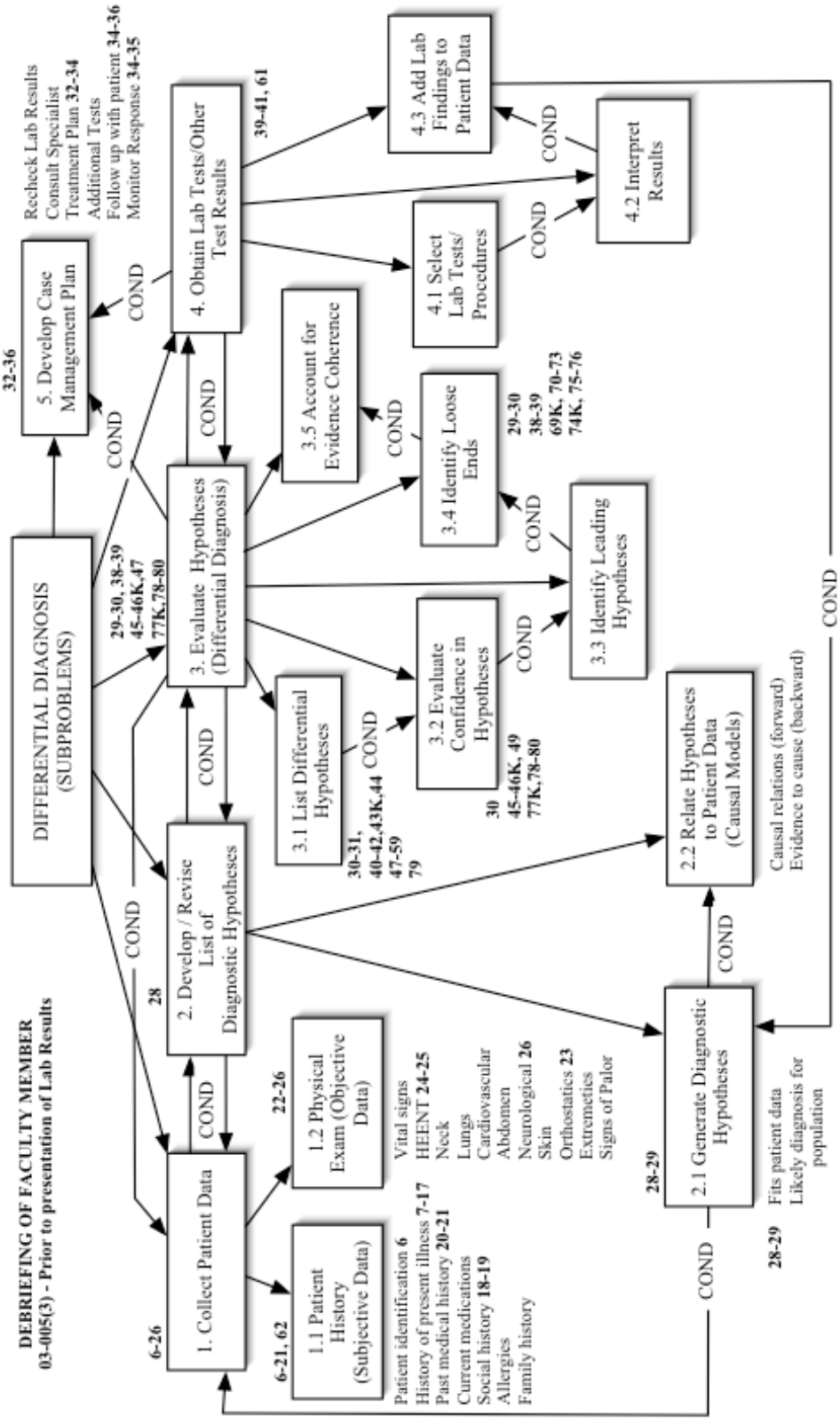
At text unit 42 until 80, the sequence is organized as subject responses to questions from the interviewer that involve the sequence:

1. List differential hypotheses (43)
2. Evaluate confidence in hypotheses (45-46)
3. Lab tests (61)
4. Identify leading hypothesis (64)
5. Management plan (66)
6. Evaluate confidence in hypotheses (77)

This sequence of interviewer questions focuses on (3) the evaluation of hypotheses, and also on the lab tests (4) and the patient management plan (5). The subject responds to these questions, using them to elaborate on her problem solving processes in relation to these schema components. Thus, the content of the dialogue consists of the subject's elaborations of her problem-solving and diagnostic reasoning processes, as framed by the differential diagnosis schema.

In 82-84, the interviewer presents the subject (the experienced physician) with the lab test results (see Figure 2) and asks the subject to talk while she is thinking about them. Text units 86-169 consist of a "talk-aloud protocol" by the subject as she reviews the lab test results and revises her differential diagnosis. Thus, this part of the discourse consists of a real-time problem-solving protocol in which the subject models her problem-solving processes in the context of her dialogue with the interviewer. A trace of her application of the differential diagnosis schema as she revises her diagnosis given the lab tests is given in Figure 5. In this Figure, the four lab tests are listed in the schema as components of node 4.1 (select lab tests) and 4.2 (interpret results).

Figure 4 – Schema Trace of Faculty Member Debriefing: Review of SOAP Note



It can be seen in Figure 5 that her problem solving consisted of applying all of the schema components as she: (2) developed new diagnostic hypotheses, (3) evaluated her initial hypotheses in relation to her new hypotheses, and (4) interpreted the lab test results, and (5) developed a new case management plan. In the subsequent results, we will examine the processes and knowledge she applied in each component of her problem-solving. The trace analysis of her discourse reveals that the discourse macrostructure reflects the systematic application of the differential diagnosis schema to organize her cognitive processes in: interpreting the lab test results, generating hypotheses, relating them to the patient data, all aspects of evaluating hypotheses to arrive at a new differential diagnosis for the case, and developing a new treatment plan.

The episodic structure of the discourse consists of a sequence of problem-solving episodes that is reflected in the organization of the discourse. A discourse episode is a segment of discourse that corresponds to an single episode of problem solving. The schema trace shows the mapping from the hierarchical structure of the problem solving to the sequential structure of episodes that are reflected in the discourse. To examine the cognitive processes that are functioning during clinical problem solving, we will need to analyze the content of the discourse and problem-solving within and across sequences of episodes. The hierarchical organization of the schema corresponds to the macrostructure organization of episodes within the discourse.

In Figure 6, the Summary of Case Evidence at the beginning of the debriefing interview is given (text units 5-26) with the episode structure represented as "bars" (to the right of the lines of transcribed discourse). The top-level schema component corresponding to this stretch of discourse is (1) collect patient data. The protocol consists mostly of sub-components of the (1.1) subjective data component, and then shifts to the (1.2) objective data component. Within the subjective data component, the sequence of sub-components is: patient identification, history of present illness, social history, and past medical history. For each discourse episode, the subject relates her findings during the clinical exam.

A second example is given in Figure 7 where the subject is reviewing the Assessment part of her SOAP Note. Here the first text unit corresponds to an episode in which she is: (2) developing a list of diagnostic hypotheses by (2.1) generating a diagnostic hypothesis, and (2.1.1) fitting patient data. She then shifts to (3) evaluating hypotheses by (3.4) evaluating loose ends, (3.1) listing a differential hypothesis, and (3.2) evaluating her confidence in the hypothesis.

To summarize our results, all three subjects used the differential diagnosis schema to guide their clinical problem solving. The application of the schema can be seen in the trace of the sequence in which schema components occurred in the discourse. The faculty member differed from the resident and the student in the specific content of her discourse and actions when undertaking specific components of the schema. The discourse was found to be organized into a sequence of episodes that correspond to main components and sub-components of the differential diagnosis schema.

Figure 5 - Schema Trace of Faculty Member Debriefing: Revision of Diagnosis following Receipt of Lab Test Results

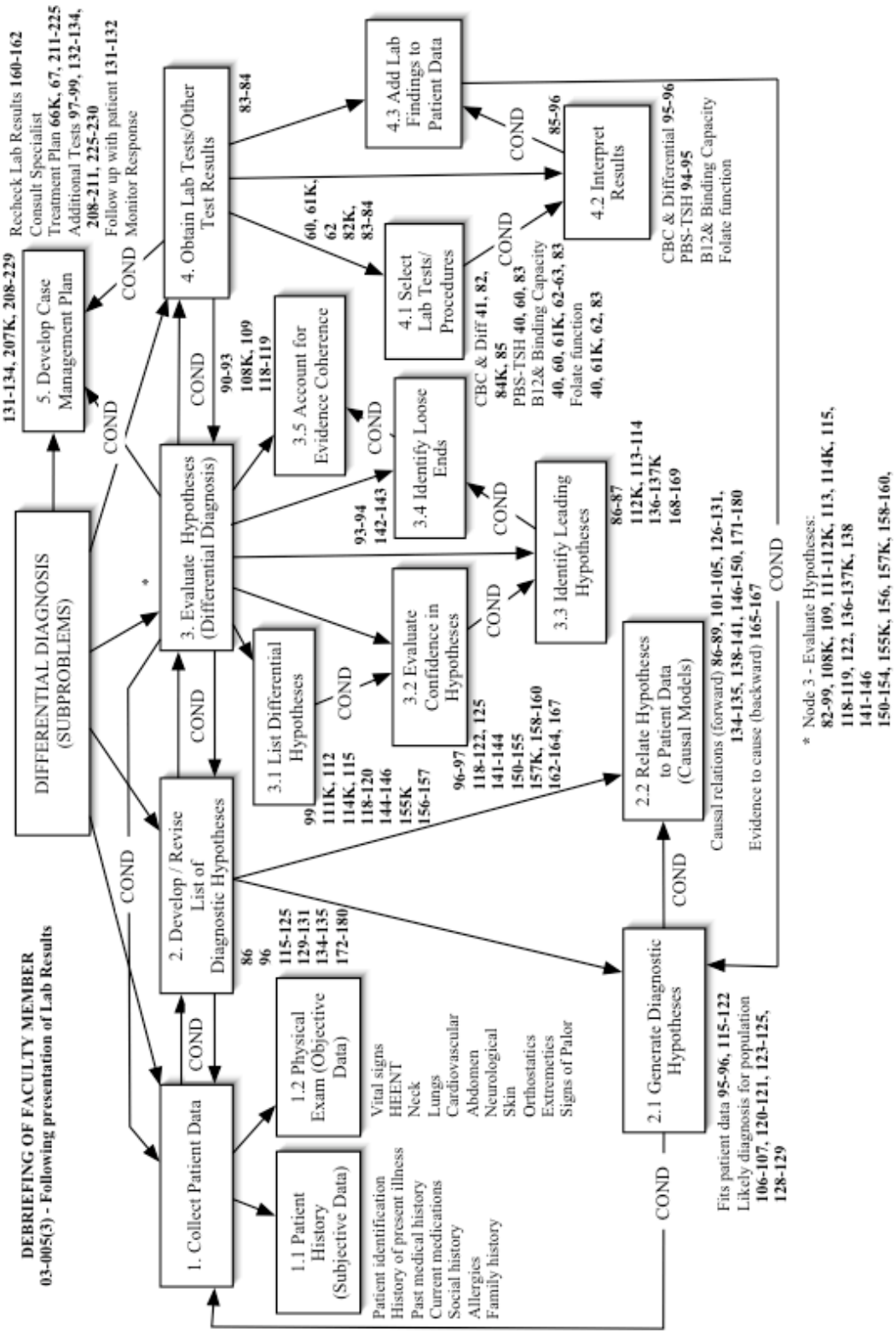


Figure 6 – Example Illustrating the Episodic Structure of Clinical Discourse (1)

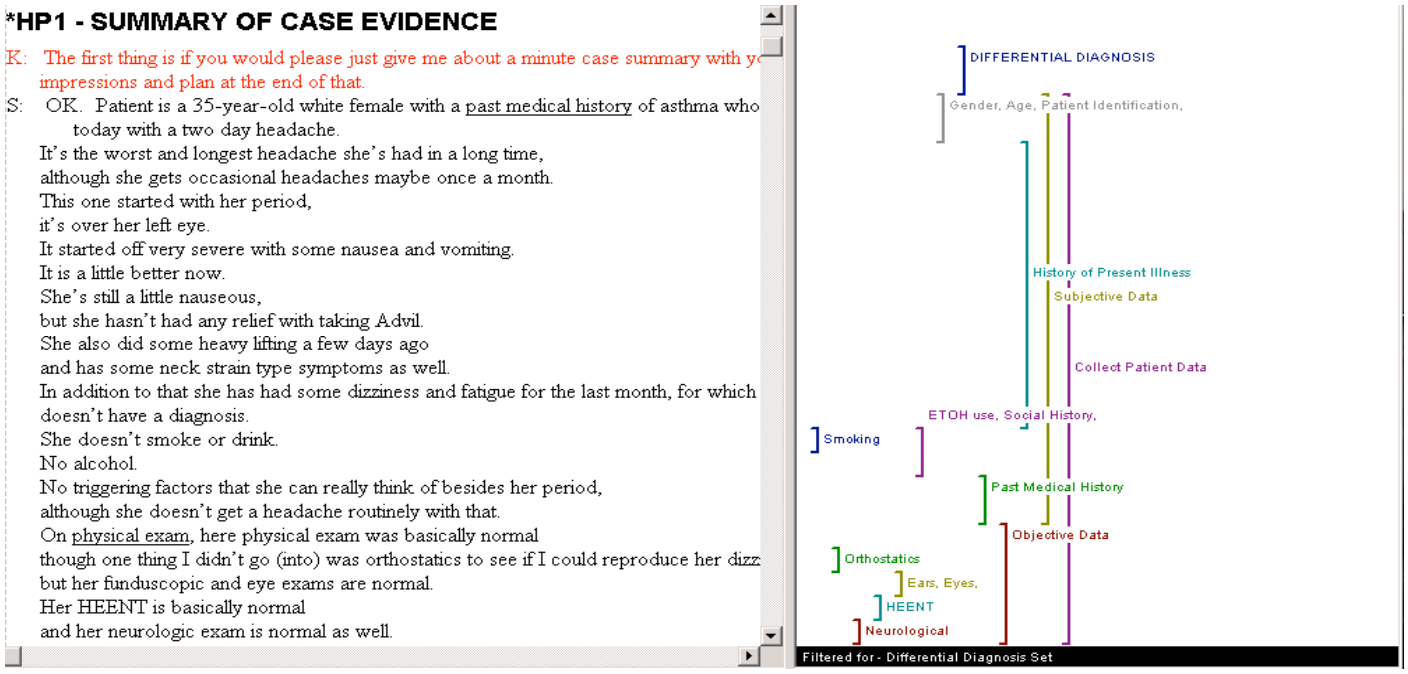
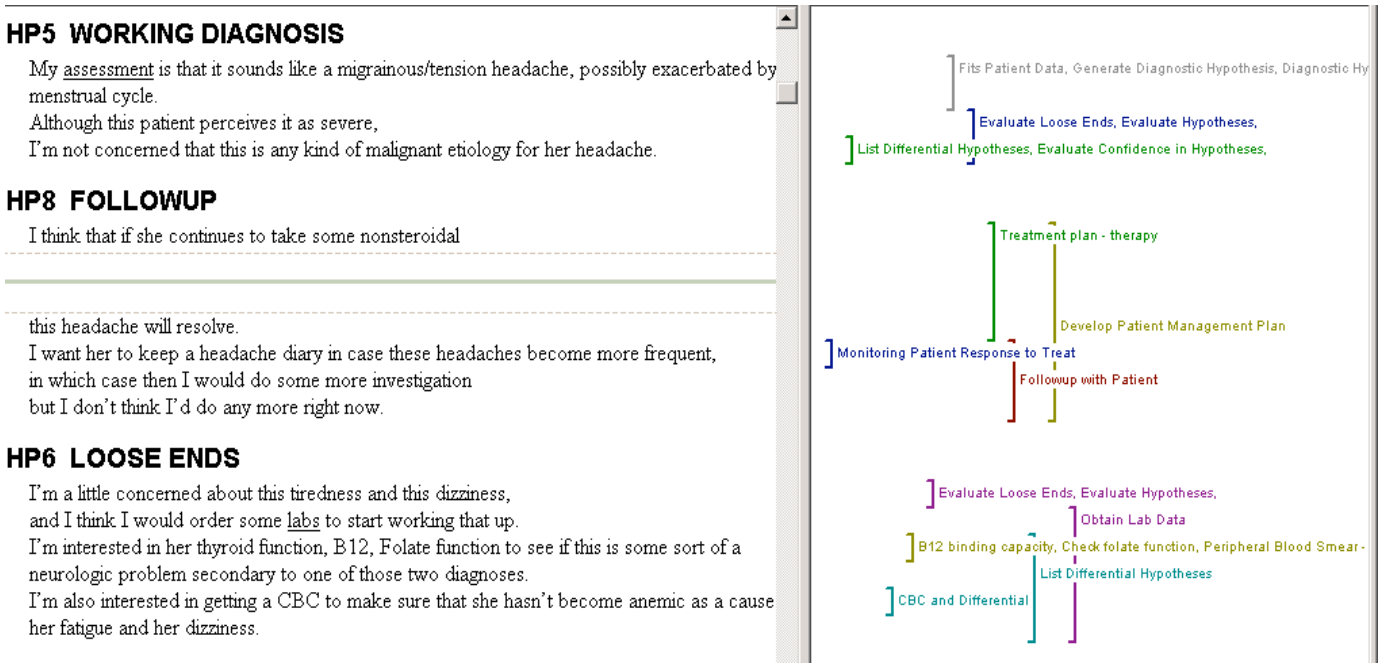


Figure 7 – Example Illustrating the Episodic Structure of Clinical Discourse (2)



2. The construction of a case representation: the collection of patient data

We investigated the process of constructing a case representation by focusing on the SOAP Notes written by the subjects, i.e., the "Gold Standard" SOAP Note written by the expert, and the SOAP Notes written by the faculty member, the resident, and the medical student. The SOAP Note summarizes the results of the patient examination in the SP encounter.

Detailed analysis of the dialogue between the "Subject" (i.e., the faculty member, the resident, or the medical student) with the SP in the situation of the patient examination (the SP encounter) is planned. An initial comparison of the faculty member with the resident revealed that they used different interview formats. Both began the data gathering process with "How can I help you?" to mark the beginning of the process of eliciting information about the patient's problem (i.e., the "history of present illness"). The faculty member followed this with questions directed at the current problem (68 questions before beginning the medical examination). The resident preceded this "question" with an "introduction". Following the question, the resident turned to "background history" and only by question 33 did he return to the headache (the principal complaint of the patient) and questions related to the "history of present illness". During questions directed at the "history of present illness", the faculty member and the resident elicited similar information, but at very different points within the interview.

The SOAP Note includes a section for the description of Subjective and Objective Data for the case, as well as for the description of hypotheses (the Assessment) and the planned follow up (the Plan; see Figure 1). The differential diagnosis schema for (1) collect patient data specifies two kinds of patient data: (1.1) subjective data and (1.2) objective data, and lists categories of information for each (see the schema diagram in Figure 3). Based on the case information data provided by the SP, a list of clinical data for each of these categories of subjective and objective data was generated. During the SP encounter, the SP provides this information to the "Subject" (the faculty member, the resident, or the medical student) in response to questions eliciting this information. Thus, the SP encounter simulated the diagnostic interview in which the physician has to systematically "dig out" the clinical data through interactions with the patient, and use this information to construct a representation of the case (i.e., of the clinical situation). The accuracy and completeness of this representation of the case data can have a direct impact on the development of a differential diagnosis for the case.

The entire dialogue was segmented into discourse units, and these were coded in terms of speaker turns (of the Subject and the SP). Then, each discourse unit was coded in terms of the differential diagnosis schema and the clinical data corresponding to each category of subjective or objective data. The resulting coding provides a detailed record of clinical data elicited by each Subject and the sequence in which the information was elicited from the SP. The frequency (and sequence) of each reference to a component of the clinical data by the experienced physician, the medical student, and the resident can be compared, and the frequencies of reference to clinical data components of all three Subjects can be compared to those of the expert in the Gold Standard SOAP Note (i.e., information in the Patient Information, Presenting Situation, Subjective Data, and Objective Data sections of the SOAP Note).

Table 1 presents the frequencies of node references in the SOAP Notes to schema components (i.e., items of subjective data) by the three subjects (Faculty Member, Resident and Student) as well as by the expert (in the "Gold Standard" SOAP Note in Figure 1).

Table 1

History of Present Illness: Frequencies of Node References in SOAP Note

Node	Schema Component	Faculty	Resident	Student	Expert
(2 1 1)	/PATIENT DATA/Subjective Data /History of Present Illness				
(2 1 1 1)	/Unilateral headache for 2 days	2	2	1	3
(2 1 1 1 1)	/Left side	1	2	1	0
(2 1 1 1 2)	/throbbing pain	0	0	1	0
(2 1 1 2)	/Scotoma at headache onset 'squiggly	1	1	1	2
(2 1 1 2 1)	/symptoms resolved in 1 hr	0	0	1	0
(2 1 1 3)	/Episode of vomiting at onset of head	1	1	1	1
(2 1 1 3 1)	/vomiting has resolved	0	0	1	0
(2 1 1 4)	/Nausea since headache onset	2	0	1	1
(2 1 1 5)	/Vision 'pretty much 20-20' since the	0	2	0	1
(2 1 1 6)	/Started menses on day 1 of headache	1	1	1	1
(2 1 1 6 1)	/currently menstruating	0	0	1	0
(2 1 1 7)	/Cleaned garage 5 days ago	1	0	0	1
(2 1 1 9)	/Daily headache in back of head since	1	1	0	1
(2 1 1 9 1)	/less severe	1	1	0	0
(2 1 1 10)	/Fatigue	1	1	1	2
(2 1 1 10 1)	/for 1 to 2 months	1	0	1	0
(2 1 1 11)	/Dizziness DZ	1	1	0	1
(2 1 1 11 1)	/DZ worsening over past month	0	0	0	1
(2 1 1 11 2)	/DZ worsened by postural changes	0	1	0	1
(2 1 1 11 3)	/for 1 to 2 months	1	0	0	0
(2 1 1 12)	/Lightheadedness LH	0	0	0	2
(2 1 1 12 1)	/LH worsening over past month	0	0	0	1
(2 1 1 12 2)	/LH worsened by postural changes	0	0	0	1
(2 1 1 13)	/Skin 'feels itchy'	0	0	0	1
(2 1 1 14)	/Legs and feet fall asleep when on st	1	1	2	1
(2 1 1 14 1)	/for past month	0	0	0	1

Table 1 (cont.)

History of Present Illness: Frequencies of Node References in SOAP Note (cont.)

Node	Schema Component	Faculty	Resident	Student	Expert
*(2 1 1 15)	/Denies nasal congestion	0	0	0	1
*(2 1 1 16)	/Denies weakness	0	1	0	1
*(2 1 1 17)	/Denies numbness	0	0	0	1
*(2 1 1 18)	/Denies chest pain	0	1	0	1
*(2 1 1 19)	/Denies shortness of breadth	0	1	0	1
*(2 1 1 20)	/Denies weight loss	0	0	0	1
*(2 1 1 21)	/Denies fever	0	1	0	1
*(2 1 1 22)	/Denies sleep disturbances	0	1	0	1
(2 1 1 23)	/Neck occipital pain	1	0	0	0
(2 1 1 24)	/Headache is constant	1	0	0	0
(2 1 1 25)	/Headache severe onset then improved	1	1	1	0
(2 1 1 26)	/Worst and longest headache she can r	1	0	1	0
(2 1 1 28)	/Headache does not worsen with positi	1	0	0	0
*(2 1 1 27)	/No complaint of photophobia	1	1	0	0
*(2 1 1 29)	/Reports no sinus congestion	1	0	0	0
*(2 1 1 30)	/Denies any new stresses	0	1	0	0
*(2 1 1 31)	/Denies triggering event or injury	0	0	1	0
*(2 1 1 32)	/Denies appetite changes	0	1	0	0
*(2 1 1 33)	/Denies changes in bowel or bladder h	0	1	0	0

We may group the symptoms in Table 1 into:

1. Symptoms present at the onset of the headache: (2 1 1 1) – (2 1 1 3)
2. Related symptoms and events during the 2 months following onset of the headache: (2 1 1 3 1) – (2 1 1 14 1), (2 1 1 23) – (2 1 1 26), (2 1 1 28)
3. Negative symptoms (marked with an asterisk): symptoms <u>not</u> present since onset of the headache (2 1 1 15) – (2 1 1 22), (2 1 1 27), (2 1 1 29) – (2 1 1 33).

If we consider the "expert" column, we can see those case facts that were listed in the expert SOAP note as important to the diagnosis of the case following the initial patient interview. The expert focused on the onset events: a unilateral headache with a 2 day duration, scotoma at onset, and episode of vomiting at onset. The following continuing effects were noted by the expert: nausea, daily headache (back of head), fatigue, dizziness and lightheadedness (worsening over past month and by postural changes), itchy skin, and legs and feet falling asleep. The list of "negative" symptoms reported by the expert is important in enabling rejection of potential alternative diagnostic hypotheses. The expert SOAP Note does not include neck pain, some details about the headache, and additional "negative" symptoms.

The frequency data for the faculty member (column one in Table 1) indicate that all of the headache symptoms reported by the expert (onset and continuing symptoms of headache) were elicited by the faculty member except the lightheadedness and itchy skin symptoms, the return to normal vision after the headache, and some details related to the headache, fatigue and dizziness. None of the negative symptoms reorted by the expert were noted in the faculty member's SOAP

Note, but neck pain, and the lack of photophobia and sinus congestion were listed by the faculty member.

The medical student listed the main complaint of headache (including some details), scotoma, and vomiting. The student missed many of the effects that continued over the 2 month period following onset: daily headache, dizziness, lightheadedness and itchy skin, but did list nausea, fatigue, and legs and feet fall asleep. The student also listed that the headache was severe but improved after onset, but reported none of the negative symptoms listed by the expert (but did report four negative symptoms not listed by the expert).

The resident listed the onset symptoms, the symptom that the SP's legs and feet fall asleep, and that the headache was severe but improved. However, the resident missed the nausea, lightheadedness, and itchy skill symptoms that were identified by the expert. The resident lists some of the negative symptoms noted by the expert, as well as additional negative symptoms; and notes that the headache improved.

These results indicate differences among the three subjects: the faculty member's symptom list related to the primary event of the headache onset and its after effects was very similar to that of the expert (i.e., the Gold Standard SOAP Note): only the lightheadedness symptom was missed. The resident missed three symptoms related to the headache event and its after effects: nausea, lightheadedness and itchy skin; and the student missed 10 symptoms and details including: daily headache, dizziness, lightheadedness, and itchy skin. The student did not list any of the negative symptoms listed by the expert. Thus, these data show that the three subjects at different levels of knowledge and experienced varied in the subjective data they elicited and included in their "case model". Subjects with more training and clinical experience were more similar to the expert in the symptoms they elicited and included in their "case models".

The expert identified three main clinical events that occurred in the patient's past medical history: (a) past history of asthma (controlled with inhaler), (b) irritable bowel syndrome (controlled with Metamucil), and (c) an episode of stress related depression (treated at time of episode). The faculty member listed only the asthma. However, the history of irritable bowel syndrome was identified in the interview with the SP. The faculty member also included facts about the history of monthly headaches, and noted the lack of a recent eye exam. The resident list two of the main clinical events, but (like the faculty member) also missed the episode of stress related depression. The resident also listed the history monthly headaches (probably associated with the female patient's periods), and the lack of recent illnesses, or past surgeries. The medical student listed the three main clinical events identified by the expert: asthma, irritable bowel syndrome, and the episode of depression. The student also listed the lack of past surgeries, and the lack of a recent eye exam or viral illness were elicited from the SP in the interview but were not included in the SOAP Note.

Thus, all three of the subjects were similar to the expert in eliciting information about the patient's medical history, except that the faculty member and resident did not identify the episode of stress-related depression. All three elicited information about the patient's lack of a recent eye exam, following up on the visual symptoms. Both the faculty member and the resident focused on the headache, identifying the SP's history of monthly headaches (associated with the patient's periods). In addition, the resident and the student elicited additional information about the patient's lack of recent viral illnesses or history of past surgeries. Thus, the subjects were similar to each other in the past medical history part of the examination. The expert provided less information in the SOAP Note, which may reflect a lack of inclusion of negative information in the written report (i.e., events not in the patient's past medical history).

Table 2

Select Lab Tests: Frequency of Node References in Debriefing Interview

Node #	Schema Component	Faculty	Resident	Student
(1 4 1)	/DIFFERENTIAL DIAGNOSIS /Obtain Lab Data /Select Lab Tests			
(1 4 1 1)	/CBC and Differential	2	3	1
(1 4 1 2)	/Peripheral Blood Smear - TSH	3	1	1
(1 4 1 3)	/Arterial Blood Gases	0	1	0
(1 4 1 4)	/B12 binding capacity	4	2	0
(1 4 1 5)	/Bone Marrow Biopsy	0	0	0
(1 4 1 6)	/Check folate function	3	2	0
(1 4 1 7)	/ESR for temporal arteritis	0	1	0
(1 4 1 8)	/BNP for electrolyte abnormalities	0	1	0
(1 4 1 9)	/MRI	0	2	0
(1 4 1 10)	/carotid studies	0	2	0
(1 4 1 11)	/hemocult	0	2	0
(1 4 1 12)	/rest of workup for anemia	0	2	0
(1 4 1 13)	/monitor pulse rate under exertion	0	1	0
(1 4 1 14)	/chem 7	0	0	1
(1 4 1 15)	/CT imaging	0	0	3
Total		12	20	6

With respect to the objective patient data included in the SOAP Notes, the results for the components of the physical examination were as follows:

1. Vital signs: yes (expert, resident, student), details (expert)
2. HEENT: yes (expert, faculty member, student), details (faculty member, student)
3. Neck: yes, details (expert, faculty member)
4. Cardiovascular: yes (expert, resident, student), details (expert, resident, student)
5. Lungs: yes + details (expert, resident, student)
6. Abdomen: yes + details (expert, resident, student)
7. Extremities: yes + details (expert)
8. Neurological: yes + details (expert, faculty member, resident)

The expert SOAP Note was very complete in its coverage of the components of the physical exam. The faculty member appears to have been selective in her coverage of the physical exam in her SOAP Note, including HEENT, Neck, and Neurological information in her report. The resident and the student included more information in their reports than the faculty member, but varied in what they covered. Only the expert included information about the examination of Extremities, and only the expert and faculty member included information about the Neck examination. A further analysis of the videotapes of the physical exams will be necessary to clarify what actually occurred in the examination.

Finally, the faculty member, resident, and medical student differed in the lab tests they ordered. The expert ordered two lab tests: the CBC and Differential, and the peripheral Blood Smear and TSH (Figure 2) which provide a wide range of blood test data. As may be seen in Table 2, all of the subjects requested these tests. The faculty member and the resident also ordered a test of B12 Binding Capacity . The resident also ordered a variety of other tests including and MRI, and a workup for anemia. The medical student order a CT scan and chem 7. The faculty member was most similar to the expert, focusing on a variety of blood test data.

The results of this comparison of the expert ("Gold Standard"), the faculty member (experienced physician), the resident, and the second-year medical student may be summarized as follows. All the subjects differed from the expert in the patient data they reported in their SOAP Notes. The faculty member was similar to the expert: both the expert and the faculty member reported on the major presenting complaint (the headache). Like the expert, the faculty member conducted a systematic and focused physical exam, while the resident and the medical student were less complete and systematic in their representation of the patient data. The faculty member was more focused in ordering lab tests than were the resident and the student. Generally, the analysis of the case representations based on the clinical discourse differentiated among the three subjects, and provided information about their process of collecting and interpreting patient data.

3. Construction of the differential diagnosis: generation and evaluation of diagnostic hypotheses

In this section, we present results relating to the processes involved in generating and evaluating diagnostic hypotheses to construct a differential diagnosis for the case, including *diagnostic reasoning* processes. Diagnostic hypotheses link causes (disorders) to specific symptoms or patterns of symptoms. Results will be presented comparing the experienced physician's generation and evaluation of diagnostic hypotheses to that of the medical student and the resident.

The hypotheses reported in the SOAP Note were constructed before the subjects received the lab test results. Table 3 compares frequencies of reference to specific hypotheses in the SOAP by the subjects and by the expert. The expert and faculty member focused on a diagnosis of headache with migraine and tension components. The faculty member also considered additional diagnostic explanations linked to the neck strain, postural dizziness, fatigue and numbness and tingling symptoms: heavy lifting, anemia, dehydration, neurological deficit, lumbar neuropathy and sciatic nerve compression.

The resident and the student missed the tension diagnosis, but they included other diagnoses in their differentials. The resident and the student both focused on migraine as the cause of the headache, and both identified anemia as a cause of the dizziness and fatigue, and temporal arteritis and abnormal vascular mass as possible causes of the headache. The resident identified stress or depression and a viral syndrome as possible causes of the headache, and postural hypotension as a cause of the dizziness. The student mentioned hypothyroidism as a possible cause of the fatigue.

Table 3

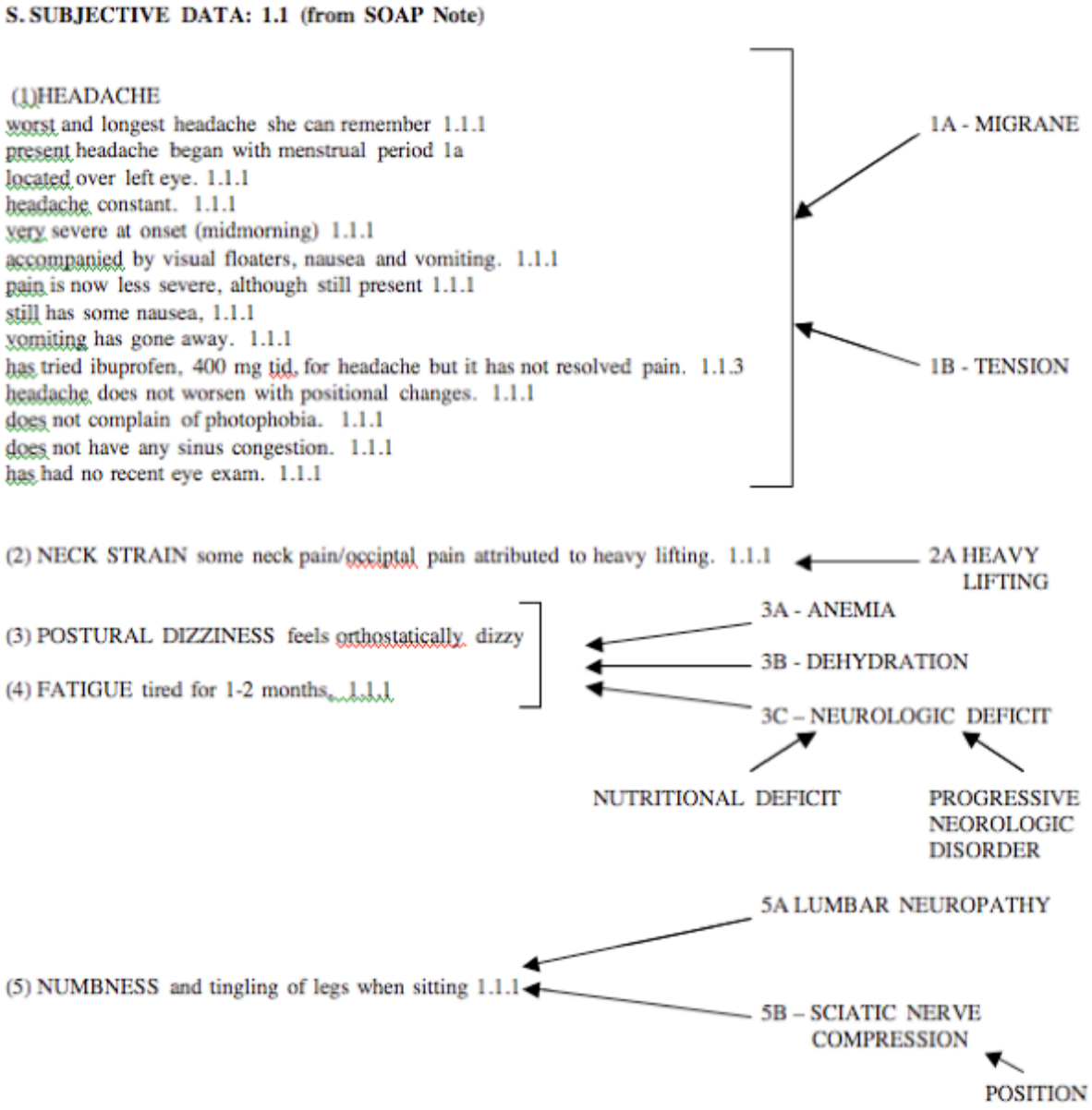
Assessment: Frequencies of Node References in SOAP Note

Node	Schema Component	Faculty	Resident	Student	Expert
(3)	/ASSESSMENT				
(3 1)	**/Migraine**	**1**	**1**	**1**	**1**
(3 1 1)	**/Headache HA caused by Migraine**	**1**	**1**	**1**	**1**
(3 1 2)	/Nausea secondary to HA	0	0	1	0
(3 2)	**/Tension**	**1**	**0**	**0**	**1**
(3 2 1)	**/Headache HA caused by tension**	**1**	**0**	**0**	**1**
(3 3)	/Neck strain due to heavy lifting	1	0	0	0
(3 4)	/Anemia	2	2	1	0
(3 4 2)	/Postural dizziness due to Anemia	1	1	0	0
(3 4 3)	/Fatigue due to Anemia	1	1	1	0
(3 5)	/Dehydration	2	0	0	0
(3 5 1)	/Postural dizziness due to dehydration	1	0	0	0
(3 5 2)	/Fatigue due to dehydration	1	0	0	0
(3 6)	/Lumbar neuropathy LN	1	0	0	0
(3 6 1)	/Numbness of legs due to LN	1	0	0	0
(3 6 2)	/Tingling of legs due to LN	0	0	0	0
(3 7)	/Sciatic nerve compression SNC	2	0	0	0
(3 7 1)	/Numbness of legs due to SNC	1	0	0	0
(3 7 2)	/Tingling of legs due to SNC	0	0	0	0
(3 8)	**/Polysythemia vera**	**0**	**0**	**0**	**1***
(3 9)	/Myelodysplastic Syndrome	0	0	0	0
(3 10)	/Epogen Use	0	0	0	0
(3 11)	/Drug Use	0	0	0	0
(3 12)	/Renal Cell Malignancy	0	0	0	0
(3 13)	/Serious Lung Disease	0	0	0	0
(3 14)	/Neuro deficit	2	0	0	0
(3 14 1)	/Postural dizziness due to Neuro	1	0	0	0
(3 14 3)	/Fatigue due to Neuro deficit	1	0	0	0
(3 15)	/Stress or depression	1	1	0	0
(3 15 1)	/Fatigue due to stress or depression	1	0	0	0
(3 15 2)	/Headache due to stress	0	1	0	0
(3 16)	/Temporal arteritis TA	0	1	1	0
(3 16 1)	/TA causing HA	0	1	1	0
(3 17)	/avm - abnormal vascular mass effect	0	1	1	0
(3 17 1)	/avm causing HA	0	1	1	0
(3 18)	/viral syndrome	0	1	0	0
(3 18 1)	/Viral syndrome causing HA	0	1	0	0
(3 19)	/Postural hypotension PosHypo	0	1	0	0
(3 19 1)	/PostHypo causing dizziness	0	1	0	0
(3 20)	/Eye strain	1	0	0	0
(3 20 1)	/Eye strain causing Headache HA	1	0	0	0
(3 21)	/Hypothyroidism	0	0	1	0
(3 21 1)	/Fatigue due to hypothyroidism	0	0	1	0

Note – Hypothesis reported in the Addition to the SOAP Note written after the expert had seen the lab results.

The debriefing interview provided an opportunity to gain some insight into the faculty member's reasoning in arriving at her differential diagnosis. A diagrammatic representation of her reasoning is given in Figure 8. Here, groupings of related symptoms she identified in her SOAP Note are listed under the headings: (1) Headache, (2) Neck Strain, (3) Postural Dizziness, (4) Fatigue, and (5) Numbness and tingling of legs when sitting. In her interview, she identifies two explanations of the headache symptoms: 1A Migrane and 1B Tension. She attributes neck strain to 2A heavy lifting. The postural dizziness and fatigue are attributed to 3A anemia, 3B dehydration, or 3C neurological deficit (this latter cause is attributed either nutritional deficit or progressive neurological disorder). Finally, the numbness and tingling are attributed to 5A lumbar neuropathy, or 5B sciatic nerve compression exacerbated by position.

Figure 8 – Faculty Member's Reasoning before Receipt of Lab Test Results
(from Debriefing Interview)



Following the review of the SOAP Note, the subjects were presented with the results of the lab tests (see Figure 2) consisting of the CBC and Differential, Peripheral Blood Smear results, and other results. The subjects verbalized their thinking as they reviewed these new results. Note, that values in the lab tests that are unusual are marked with an asterisk on the results (Figure 2). Anomalous results are: elevated RBC Count, Hemoglobin, Hematocrit, RDW, Platelet Count, and ABS Eosinophils in the CBC results; and elevated percent CO2 in the Arterial Blood Gases. Table 4 shows the frequencies of references to lab test results made by each subject in the debriefing interview. The expert included "recheck the CBC, Peripheral Blood Smear, ABG, B12 binding capacity" in the Plan section of the SOAP Note. Like the expert, the faculty member focused on the CBC and Differential, the Peripheral Blood Smear, and the Arterial Blood Gases, but made no reference to B12 levels. The resident and the student both referred to the CBC and Differential, and the Peripheral Blood Smear, and in addition, to various blood chemistry (chem 7) results. Thus, the resident and the student did not focus their references to lab test results in the same manner as did the expert and the faculty member.

Table 4

Interpret Lab Test Results: Frequency of Node References in Debriefing Interview

Node #	Schema Component	Faculty	Resident	Student
(1 4 2)	/DIFFERENTIAL DIAGNOSIS /Obtain Lab Data /Interpret Lab Test Results			
(1 4 2 1)	/CBC and Differential*	2	3	5
(1 4 2 2)	/Peripheral Blood Smear – TSH*	1	1	1
(1 4 2 3)	/Arterial Blood Gases*	1	0	0
(1 4 2 4)	/B12 binding capacity*	0	0	0
(1 4 2 5)	/Bone Marrow Biopsy	0	0	0
(1 4 2 6)	/chem 7 - BNP	0	1	3
(1 4 2 6 1)	/chem 7 - BNP/Potassium	0	1	3
(1 4 2 6 2)	/chem 7 - BNP/Sodium	0	1	2
(1 4 2 6 3)	/chem 7 - BNP/Glucose	0	1	1
(1 4 2 6 4)	/chem 7 - BNP/Chloride	0	0	2
(1 4 2 6 5)	/chem 7 - BNP/Creatinine	0	1	2
(1 4 2 6 6)	/chem 7 - BNP/BUN	0	1	2
(1 4 2 6 7)	/chem 7 - BNP/Sed rate	0	0	1
(1 4 2 9)	/CO2	0	0	1
Total Frequency		4	10	23

The clinical discourse in the debriefing session reflects the reasoning that was taking place as the subject interpreted the lab test results, generated new diagnostic hypotheses, and subsequently modify the differential diagnosis taking the new hypotheses into account. In the present situation, the debriefing dialogue consisted of a kind of think-aloud protocol produced as the subject was reasoning to generate new hypotheses from the lab data, evaluate the hypotheses, and modify the differential.

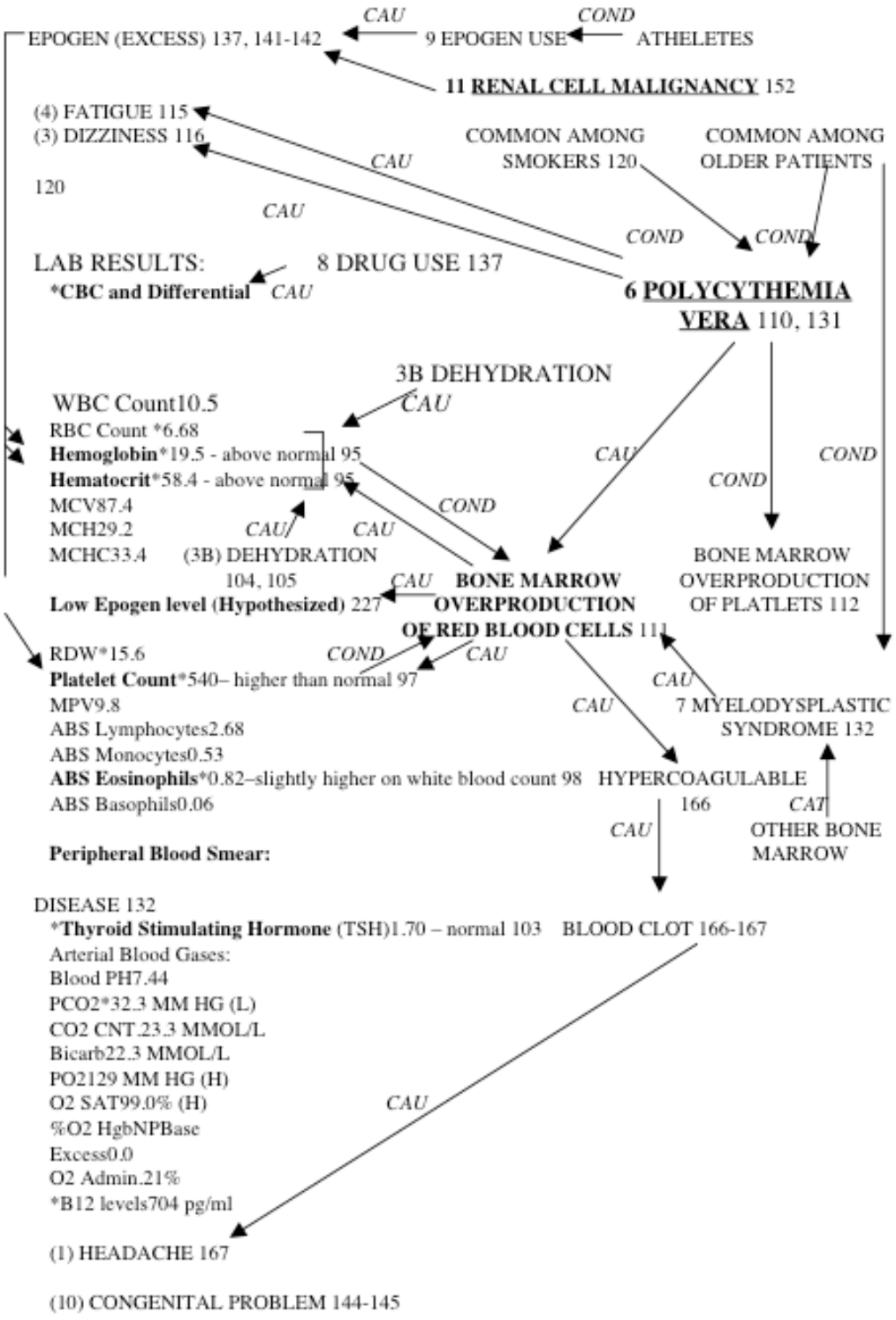
To illustrate this clinical reasoning dialogue, an excerpt from the faculty member's debriefing interview is given in Table 5 in which the faculty member is generating a new diagnostic hypothesis of *Polycythemia Vera*. A diagrammatic representation of the reasoning exhibited by this dialogue is given in Figure 9.

Table 5

Excerpt from Faculty Member's Debriefing Interview: Generation of Diagnosis of Polycythemia Vera

Well she has polycythemia which means her hemoglobin and hematocrit are above normal.
Her MCV is normal.
Her platelet count is higher than normal.
The differential eosinophils are slightly high on her white blood cell count.
I'm kind of surprised by these findings.
It certainly makes me think of a different differential for all of her symptoms.
Possibly even maybe her headache,
although I think her headache could still be outside of what these results might indicate.
I think this TSH result is normal.
With a high hemoglobin and hematocrit, what I think about is dehydration,
although there's really no reason why I would think that this patient would be dehydrated.
*(1.2 PHYSICAL EXAM)
If I could do a physical examination maneuver I'd do orthostatic blood pressures to try to figure that out,
*(2.2 LINK DIAGNOSTIC EXPLANATIONS TO THE EVIDENCE)
but the other diagnosis is polycythemia vera
which is a problem with the bone marrow producing too many red blood cells.
It can be accompanied by overproduction of other cells like the platelets.
She may have a bone marrow based problem that is causing the results on this CBC,
and patients who have that can have some symptoms.
I'm not sure if fatigue is one of them.
Dizziness might be one of them.
I guess what is more troubling to me is that I'm not sure why she would have developed this problem,
it's pretty common in smokers and in older people
but she is younger than most people I would expect to have a problem like this.
K: So it seems a bit out of sink.
S: Yes, this doesn't fit very well with this patient.
K: Any alternative diagnosis.
You seem to be leaning towards polycythemia vera.
S: Yes.

Figure 9 – Faculty Member's Reasoning about Polycythemia during Debriefing Interview



The debriefing dialogue in Table 5 begins just after the faculty member was presented with the lab results. Her first observation on examining the lab test results was to state that the SP "has polycythemia which means her hemoglobin and hematocrit are above normal." The faculty member observes that the SP's platelet count is higher than normal, that that her "differential eosinophils are slightly high on her white blood cell count". She states that she is "kind of surprised by these findings. It certainly makes me think of a different differential for all of her symptoms. Possibly even maybe her headache". The faculty member then identifies two explanations. First, she states that "with a high hemoglobin and hematocrit what I think about is dehydration", and that she would "do orthostatic blood pressures to try to figure that out".

Second, she states that "the other diagnosis is "polycythemia vera which is a problem with the bone marrow producing too many red blood cells". She states that "it can be accompanied by overproduction of other cells like platelets, and that "she may have a bone marrow based problem that is causing the results on this CBC". She then states that her previous hypotheses of (4) fatigue and (3) dizziness may be caused by this blood disorder. She is troubled by the fact that polycythemia vera is "pretty common in smokers and in older people but she is younger than most people I would expect to have a problem like this." She indicates that he is leaning towards a diagnosis of polycythemia vera. Notice that she does provide some elements from a causal model associated with polycythemia as a disorder of the bone marrow producing too many red blood cells.

Figure 9 is a diagram of the causal and conditional relations and pathways that she used to link possible causes to symptoms in her debriefing protocol as she examined alternative explanations of the symptoms. In addition to (3B) *dehydration* (retained from her original differential diagnosis), and the new hypothesis of (6) *polycythemia vera*, the faculty member considered: (7) *myelodysplastic syndrome* causing bone marrow overproduction of red blood cells; (8) *drug use* effecting the CBC and Differential lab results; (9) *epogen use* (as by atheletes) causing excess epogen leading to the above normal hemoglobin, hematocrit, and platelet count; and (11) *renal cell malignancy* causing excess epogen and its effects. In her reasoning, she traced a causal pathway from (6) **polycyhemia vera,** to **bone marrow overproduction of red blood** cells (resulting in (a) above normal hemoglobin, (b) above normal hematocrit, and (c) a hypothesized low epogen level), to **hypercoagulable blood**, to **blood clots** causing headaches.

The debriefing interview with the resident after presenting the lab results also led to a reconsideration of the differential diagnosis, but uncertainty and lack of precision about the diagnosis. The resident does not express a high degree of urgency about the case. The resident recognized *polycythemia* from the high red blood cell count, high hemoglobin and hemocrit levels, and high platelet count. The resident considered hematologic cancer, leukemia, and abnormal kidney function as possible causes of these abnormal lab results. The resident goes on to state that "*I guess my differential would change as well as far as-, again you know cancers of bone marrow and things like that*." The resident continues to summarize the differential as follows:

> *I think the headache-, I would still work up in that way and kind of treat it in the same way, but I would add to it the thought of the increase obviously in red blood cells and what's going on there. I don't know exactly what's going on to be honest with you and that's why I would try to find out if there is anything going on in the bone marrow. But I would add that to the headache. I'd also add that to the dizziness and the fatigue, because if you've got abnormal red cells obviously you're not going to carry oxygen properly*."

The resident also states an uncertainty about the mechanisms of bone marrow overproduction of red cells:

[overproduction] "*may not be exactly a malignancy. Polycythemia I think is not, I don't think it's defined as a cancer but you can also have overproduction of red blood cells. — "I don't know if there are differentials that go along with polycythemia as well.*"

Thus, the resident does not identify *Polycythemia vera* as a cause of the polycythemia.

The medical student also recognizes the polycythemia as a condition associated with high hemoglobin and hematocrit levels in the lab results. The student identifies "some erythropoietin secreting mass" like *renal cell carcinoma* as "at the top of my list" (i.e., as her new leading diagnosis). She states

"*that's a really high hemoglobin and when your hemoglobin gets that high your blood becomes more fiscours so she may be having some infarction, blood clots because it's not moving through very well*." She summarizes by saying: "*This shows she has some type of polycythemia, high platelet count, and her eosinophils are twice high normal*."

In revising her differential, the student is unable to come up with an explanation of the polycythemia ("something like a cancer in another organ like th kidney"). The student still states about the headache symptoms: "It still seems seem like a migraine." Then reflecting on the differential for the polycythemia, she states:

"I don't really know like what polycythemia from a erythropoiesis would look like compared to maybe a familial polycythemia which (is) polycythemia vera."

Her final differential includes cancer and *polycythemia vera* for the symptoms of a polycythemia, and retains migraine as an explanation for the headache.

These results demonstrate how analysis of the debriefing interview following the presentation of the lab tests reveals important differences between the faculty member, on the one hand, and the resident and student, on the other. These differences occur not so much in the interpretation of the lab test results, but in the generation of new diagnostic hypotheses, and success in relating hypotheses to the patient data by means of causal models. Difficulties in revising the list of diagnostic hypotheses have their roots in a lack of knowledge of the mechanisms that cause a recognized abnormality in the blood test results, i.e., the polycythemia. These difficulties lead to difficulties in evaluating the hypotheses to establish the differential diagnosis. We were able to see successful processes of generating diagnostic hypotheses and revising the differential diagnosis reflected in the analysis of the reasoning of the faculty member. The contrast with the clinical dialogue of the resident and the student was dramatic.

To evaluate quantitative differences in the processes used by the faculty member, the resident and the student in generating diagnostic hypotheses, the debriefing interviews were coded in terms of the schema components for the Diagnostic Hypotheses procedure (1 2) in the differential diagnosis schema. The results are presented in Table 6. The node frequency data show that the faculty member produced more dialogue units in generating diagnostic hypotheses, and more frequently considered the likelihood of a particular diagnosis in the population group corresponding to the SP (i.e., the likelihood of the diagnosis given the SP's population category). In terms of the direction of the inferences, the faculty member and the student were more likely to reason forward from hypotheses to the evidence, while the resident was more likely to reason backward from the patient data to possible hypotheses. All three subjects related their hypotheses to the patient data.

Table 6

Generate Diagnostic Hypotheses: Frequency of Node References in Debriefing Interview

Node #	Schema Component	Faculty	Resident	Student
(1 2)	/DIFFERENTIAL DIAGNOSIS /Diagnostic Hypotheses			
(1 2 1)	/Generate Diagnostic Hypothesis	11	5	7
(1 2 1 1)	/Fits Patient Data	5	3	7
(1 2 1 2)	/Likely Diagnoses for Population Type	4	1	2
(1 2 2)	/Relate Hypotheses to Patient Data	6	14	5
(1 2 2 1)	/Causal Relations [forward]	9	7	5
(1 2 2 2)	/Evidence to Cause [backward]	1	10	1
Total Frequency		36	40	27

Frequencies of dialogue reflecting the processes in which the subjects evaluated their diagnostic hypotheses to arriving at a differential diagnosis are presented in Table 7. Since the dialogue related to the evaluation of diagnostic was framed to a large extent by the interviewer's questions in the debriefing dialogue, the total frequency of dialogue units for each subject is similar. However, given these constraints, the faculty member was more likely to evaluate her confidence in her hypothesis, and identify a leading hypothesis based on her evaluation. The three subjects were similar in their frequency of dialogue units listing their differential hypotheses, and evaluating loose ends. The resident's frequencies of dialogue units accounting for evidence coherence were greater than the other subjects.

To summarize, the debriefing interview included the generation of diagnostic hypotheses based on the lab results. The faculty member, like the expert, identified the correct diagnosis of *polycythemia vera* (a disorder of the bone marrow leading to the overproduction of red blood cells, leading to hyperviscosity of the blood and clotting). The other subjects generated a variety of other hypotheses. The faculty member used more forward reasoning) from cause to symptoms) than backward reasoning (from evidence to cause), and the resident used more backward reasoning than forward reasoning.

Table 7

Evaluate Diagnostic Hypotheses: Frequency of Node References in Debriefing Interview

Node #	Schema Component	Faculty	Resident	Student
(1 3)	/DIFFERENTIAL DIAGNOSIS /Evaluate Hypotheses			
(1 3 1)	/List Differential Hypotheses	12	10	11
(1 3 2)	/Evaluate Confidence in Hypotheses	16	13	12
(1 3 3)	/Identify Leading Hypotheses	5	2	1
(1 3 4)	/Evaluate Loose Ends	6	6	4
(1 3 5)	/Account for Evidence Coherence	3	9	4
Total Frequency		42	40	32

The patient management plan that was produced by the expert (as given in the "Gold Standard" SOAP Note) included the schema components listed in Table 8. Based on the diagnosis of *polycythemia vera*, the expert established a plan that included: (a) rechecking of lab test results (CBC, TSH Peripheral blood smear, ABG arterial blood gases, and B12 binding capacity), (b) consulting urgently with a hematologist, (c) contacting the transfusion medicine unit to carryout a phlebotomy in which 500cc blood is replaced with normal plasma (to reduce the red blood cell count, and the likelihood of stroke or heart attack caused by blood clots), (d) evaluation by a hematologist, and (e) a probable bone marrow biopsy (to check the diagnosis of *polycythemia vera*).

Table 8

Expert Plan after Labs

Node	Schema Component
(4 2)	/PATIENT PLAN/After LABS
(4 2 1)	/Recheck CBC
(4 2 2)	/Recheck TSH Peripheral Blood Smear
(4 2 3)	/Check ABG Arterial Blood Gases
(4 2 4)	/Check B12 Binding Capacity
(4 2 5)	/Consult urgently with hematologist
(4 2 6)	/Transfusion Medicine for Phlebotomy
(4 2 6 1)	/500 cc blood replaced with normal
(4 2 7)	/Evaluation by hematologist
(4 2 8)	/Probable bone marrow biopsy

The frequency of node references in the debriefing interview based on the lab results to these components of the expert's final patient management plan are given in Table 9 for the faculty member, the resident, and the student. The faculty member planned to recheck lab test results, and planned additional tests, but did not specifically plan a therapy that included phlebotomizing to reduce the red blood cell count, nor did she include in her plan a consultation with a hematologist (she included a procedure for reducing the RBC count but did not know its name). The student's plan included rechecking lab test results, but no specific therapy was listed except continuing ibuprofen for the headache and monitoring the patient response to treatment. The resident did not call for rechecking the lab test results but did plan additional tests. Neither the resident or the student included phlebotomizing to reduce RBC counts.

Table 9

Final Patient Management Plan: Frequency of Node References in Debriefing Interview based on Lab Test Results

Node #	Schema Component	Faculty	Resident	Student
(1 5)	/DIFFERENTIAL DIAGNOSIS /Develop Patient Management Plan			
(1 5 1)	/Recheck Lab Test Results*	1	0	1
(1 5 2)	/Specialist Consult – hematologist*	0	0	0
(1 5 3)	/Treatment plan - therapy	3	0	1
(1 5 3 1)	/Phlebotomize to reduce RBC*	0	0	0
(1 5 3 2)	/Ibuprofen for headache	0	0	1
(1 5 4)	/Additional Tests*	5	4	0
(1 5 5)	/Follow up with Patient	2	2	1
(1 5 6)	/Monitor Patient Response to Treatment	1	0	1
Total Frequency		12	6	5

To summarize the results related to the development of a case management plan, the faculty member's treatment plan was similar to that of the expert (she included treatment to reduce the RBC count but could not remember the name of the procedure). The resident and the novice failed to include the two critical elements needed to treat the case (phlebotomizing to reduce red blood count, and consultation with a hematologist). The real patient subsequently died as a result of stroke caused by the *polycythemia vera*.

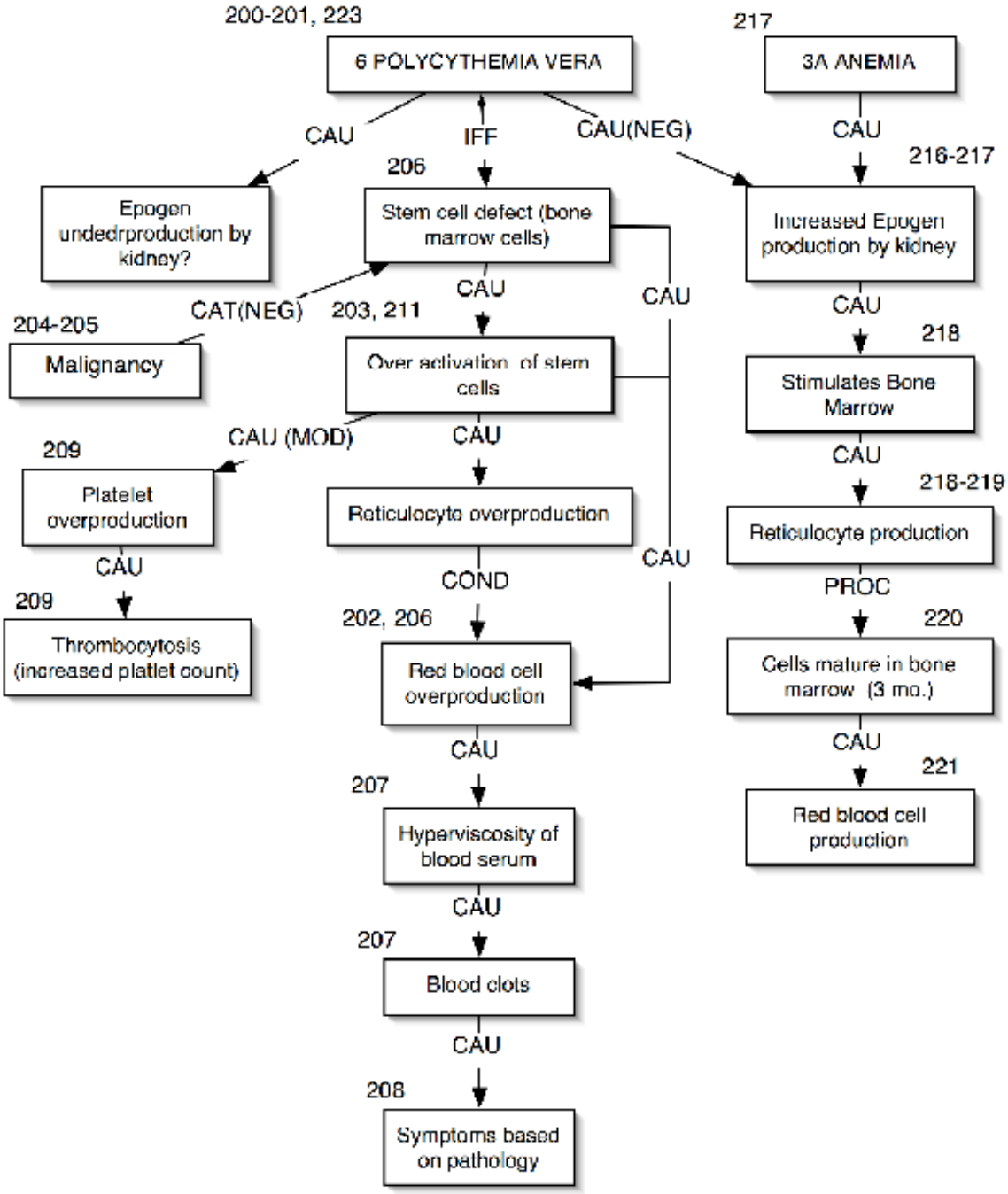
4. Use of causal models to understand and reason about the case

While the quantitative analysis revealed differences in the reasoning of the faculty member, the resident, and the student (Table 8), these differences are in themselves insufficient to explain the differences in their differential diagnoses and their treatment plans (Table 9). The qualitative analysis of the faculty member's reasoning (Figure 9) shows how this reasoning involved the application of *clinical knowledge,* e.g., the clinical knowledge schema for *polycythemia vera* linking a pattern of results from the blood tests (hemoglobin above normal, hematocrit above normal, high platelet count) to *polycythemia vera* (as the causal explanation of the pattern of blood test results). The protocol (Table 5) shows that she immediately recognized *polycythemia vera* as the diagnosis (based on pattern-matching the schema to the results). The analysis of the reasoning (in Figure 9) revealed a pattern of (mostly) forward reasoning that followed this initial diagnosis that consisted of building causal pathways to link *polycythemia vera* to both the blood test results and the symptoms of fatigue, dizziness, and headache. The faculty member also generated other alternative explanations of the clinical evidence and proceeded to evaluate the likelihood of each one. She finally settled on *polycythemia vera* as the leading hypothesis in her differential diagnosis. Her treatment plan included rechecking the blood test results and her hypothesis of a low epogen level which was deduced from the *polycythemia vera* hypothesis.

Therefore a full understanding of the faculty members process of clinical reasoning involved her knowledge of *causal models* of the physiological processes that underlie abnormal processes involved in the production of red blood cells (in *polycythemia vera,* malignancy, and anemia), and the causal processes involved in normal production of red blood cells. The faculty member's success in diagnosing the case involved her causal knowledge and facility in applying it in this diagnostic situation, both in generating the diagnostic hypothesis of *polycythemia vera* and in evaluating it against other hypotheses in developing her differential. The resident and the student differed quantitatively in their patterns of reasoning, and they both recognized the pattern of abnormal blood test results as a polycythemia. However, both lacked knowledge of *polycythemia vera* as a cause of the disorder. The student recognized that there was some kind of familial cause of the polycythemia symptoms, and eventually recalled its name (*polycythemia vera*). But neither of them was able to use their causal knowledge of the abnormal blood cell production associated with *polycythemia vera* to establish it as a leading hypothesis in the differential or use it to develop a coherent explanation of the blood test results and the other symptoms (fatigue, dizziness, headache).

To explore the subjects' knowledge of the causal mechanisms involved in *polycythemia vera*, and in anemia, malignancy, and normal red blood cell production, the interviewer asked each subject in the debriefing interview to explain what they knew of these processes. The student and the resident acknowledge that they lacked knowledge of the mechanisms of red blood cell production in *polycythemia vera* and they lacked detailed knowledge of blood production in other abnormal situations (malignancy, anemia) and in situations of normal blood cell production. Our method was to develop a representation of the causal model articulated by the expert through the propositional content of her explanations (Figure 10), and then use the expert's model to code components of the model that were articulated by the student and the resident (Table 10).

Figure 10 – Causal Models Generated by Faculty Member during Debriefing Interview



A conceptual graph representation of the faculty member's causal model of *polycythemia vera* is given in Figure 10. In this conceptual graph, the boxes contain propositions representing semantic descriptions of states, processes or events. The directional relations linking these conceptual nodes represent: causal relations (CAU) pointing from cause to effect; conditional relations (COND) pointing from an antecedent condition to a consequent state, process or event; categorical relations (CAT) pointing from a concept class to a subset of that conceptual class; process relations (PROC) pointing from a concept to a descrition of its process; and the bidirectional relation (IFF) links a concept to its logical equivalent (a semantic description or "definition" of the meaning corresponding to the concept). A modifier (NEG) attached to a link means that the link is negative, i.e., it is not present in the causal model; and a modifier (MOD) attached to a link means that it is "model", e.g., probable or likely. These links are a part of the propositional model that was applied to analyze the discourse (Frederiksen, 2001; 1986; Frederiksen & Donin, 1991).

The dialogue in which a causal model for *polycythemia vera* was articulated by the faculty member is given in Figure 11.

Figure 11

171: K: OK. In terms of the polycythemia vera, your sort of slightly #1, what is the path of physiology that would produce these findings?
172: S: Well, those patients have an increased production of their red blood cells
173: and it's I think because of a stem cell activation that is almost on the lines of a malignancy although it doesn't spread,
174: so it doesn't really fit the definition of malignancy,
175: so it's a stem cell defect that causes increase of these red blood cells to the point where patients can have clots because of the hyperviscosity of their serum.
176: They can get symptoms based on that pathology.
177: Again, it is sometimes seen with essential thrombocytosis which is the increased platelet count,
178: so you could tie those two things together with her.
179: Again, being sort of a stem cell bone marrow overproduction kind of problem.
180: K: Can you go on and just discuss what would be the normal production of red cells, what would be the mechanism for the normal production.
181: S: The normal production of red cells starts with the bone marrow with triggered-,
182: it is sort of feedback mechanism,
183: it starts with the Epogen
184: so if you develop an anemia
185: your Epogen, which is a hormone produced by the kidneys, would increase and stimulate your bone marrow to make more reticulocytes, which are the beginnings of red blood cells
186: that would then get matured in the bone marrow and pushed out in the form of red blood cells, which last for like 3 months in the body.
187: What happens with polycythemia vera is that there is not an overproduction of Epogen
188: but the stem cells and the reticulocytes are overproduced
189: because of an essential problem with the cells in the bone marrow that are producing them,
190: so you get more
191: and probably, although I'm not sure, you probably have a low Epogen level
192: because there would be no reason for Epogen to try to stimulate more production
193: since there is already overproduction.
194: K: So the Epogen is necessary for maturation or not?
195: S: I don't think so,

196: because even in patients who don't make a lot of Epogen because they have a kidney disorder, their red cells are still mature
197: there just is not enough of them,
198: so I think the Epogen is important in triggering the production of the red cells
199: but not necessarily the maturation in the bone marrow.
200: K: So at what point would you say the Epogen kicks in, in terms from stem cell to true blood cell?
201: S: I would say towards the stem cell,
202: like early on in the formation of the red blood cells,
203: but that's not something I'm real sure of.
204: K: So you are speculating right now?
205: S: Right.

Referring to the causal model of *polycythemia vera* given by the faculty member (Figure 10), the concept *polycythemia vera* is defined as corresponding to a stem cell defect involving the bone marrow cells. This defect causes an over activation of stem cells, which causes reticulocyte overproduction, a condition for red blood cell overproduction, and thus causes red blood cell overproduction. The red blood cell overproduction causes hyperviscosity of the blood serum. This hyperviscosity of the blood causes the formation of blood clots which lead to symptoms associated with this pathology. These she described previously in her clinical reasoning about the case. *Polycythemia vera* also causes epogen underproduction by the kidney, and not increased epogen production. Over-activation of the stem cells leads to platelet overproduction which causes the increased platlet count (thrombocytosis). The stem cell defect is not a type of malignancy.

In addition to this causal model, the faculty member outlines the mechanisms in which anemia can lead to increased blood cell production. Anemia leads to increased epogen production by the kidney, which stimulates the bone marrow to increase reticulocyte production (in which cells mature in the bone marrow for about 3 months). The result is increased red blood cell production. The faculty member noted that anemia leads to increased red cell production through increasing epogen levels, wheras *polycythemia vera* leads to increased red cell production by a different mechanism (related to the stem cell defect), leading to underproduction of epogen by the kidney.

Components of this model consisting of the *polycythemia vera* node (in the causal model), and each link in the model plus the node it points to (e.g., CAU + reticulocyte overproduction), were used to code the causal models articulated by the faculty member, resident and the student. In Table 10, frequencies of these node references in their debriefing interviews are recorded. The faculty member referred to each node in the causal model (except for "possible genetic cause" which was referred to by the student). The resident described *polycythemia vera* as a stem cell defect leading to overproduction of red blood cells, resulting in hyperviscosity of the blood serum. The resident referred to some symptoms based on the pathology and noted that it is not a malignancy. The student stated that *polycythemia vera* causes over-activation of stem cells causing platelet overproduction and overproduction of red blood cells, leading to hyperviscosity of the blood serum. She also described it a having a possible genetic cause.

Table 10

Polycythemia Veria: Frequences of Node References in Debriefing Interview

		Faculty	Resident	Student
(5 1)	/Causal Models/Polycythemia Vera	8	2	4
(5 1 1)	/IFF Stem cell defect	7	1	0
(5 1 2)	/CAU over-activation of stem cells	2	0	1
(5 1 2 1)	/CAU reticulocyte overproduction	3	0	0
(5 1 2 1 1)	/CAU platelet overproduction	1	0	1
(5 1 2 1 1 1)	/CAU thrombocytosis-high platelet ct.	1	0	0
(5 1 2 3)	/CAU over-activation of stem cells			
	/CAU RBC overproduction	3	4	1
(5 1 2 3 1)	/high RBC count	3	0	2
(5 1 2 3 1 1)	/CAU hypercoagulability of blood	1	0	0
(5 1 2 4)	/CAU over-activation of stem cells			
	/CAU hyperviscosity of blood serum	1	2	1
(5 1 2 5)	/CAU blood clots	2	0	0
(5 1 2 6)	/CAU symptoms based on pathology	3	2	0
(5 1 3)	/Causal Models/Polycythemia Vera			
	/RSLT epogen underproduction	1	0	0
(5 1 4)	/NEG RSLT Epogen overproduction	1	0	0
(5 1 5)	/NEG ISA malignancy	1	1	0
(5 1 6)	/Possible genetic cause	0	0	2

These results confirm the important role of causal models, in addition to clinical knowledge, in diagnostic reasoning. The difference between the differential diagnosis of the faculty member (which was like that of the expert) and those of the resident and the student cannot be explained completely by differences in their reasoning patterns (forward or backward) or to differences in their clinical knowledge (which led all three to recognize the polycythemia pattern in the blood test results). These differences appear to result from the faculty member's (and the expert's) knowledge of the causal mechanisms underlying normal red blood cell production, the stimulation of red blood cell production in anemia, and abnormal red blood cell production in *polycythemia vera*.

Conclusions

On the basis of the results presented here, we conclude that the analysis of the clinical discourse of experts and experienced physicians can be used to develop a specification of the components of clinical competency in medicine, and these models can be applied to analyze the clinical discourse of individuals at different levels of training and experience to investigate how clinical competency in medicine is develops. A comparison of the clinical discourse of an experienced physician with that of a second-year medical student and a resident showed that they all used the schema to guide their differential diagnosis and they engaged in similar processes. However, they differed greatly in their knowledge and experience. Experts and experienced physicians have extensive knowledge and are skilled in applying it to reason and solve clinical problems requiring obtaining patient data for a case, constructing a differential diagnosis, and developing a treatment plan, while "novice" medical students and "intermediate" residents display varying degrees of facility in applying their knowledge effectively in all of these different phases of clinical problem solving.

The results provide preliminary evidence that the cognitive discourse analysis methods that were applied in this study discriminate among individuals at different levels of training and experience in a manner that is informative about their underlying knowledge and facility in applying it. The methodology and the models resulting from the cognitive discourse analysis provide a basis for developing cognitive assessments of clinical competency. They also have potential application to the development of coaching systems to help medical students develop clinical competency in medicine. Analysis of clinical discourse as task-oriented discourse can thus provide a valuable method for the study of clinical expertise.

These results in one domain of clinical problem solving in medicine, if supported by additional research, have implications for the study of task-oriented dialogue and written discourse in many domains of expertise. Since task-oriented discourse occurs in well-defined performance environments, the structure of the knowledge (procedural and declarative) and of the cognitive processes underlying successful performance of task-oriented activities can be studied, and models can be used to investigate discourse processes and communicative competency in such environments. This approach can contribute to the study of the content and communicative processes involved in participating in dialogue in collaborative problem-solving and learning environments (e.g., collaborative activity in problem-solving and problem-based learning environments). The next steps in this project will be to analyze the interaction between the physician (or student) with the SP, and then to complete the analysis of the entire corpus. We hope to develop a much larger corpus using a variety of types of clinical problems in medicine.

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Appendix A

Transcription of Debriefing Interview with Faculty Member

Project: MedicalCompetnce **User:** Administrator **Date:** 7/16/2005 - 5:00:02 PM

DOCUMENT TEXT REPORT

Document: Debrief Faculty 3 03_005_3
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Description:

*DEBRIEFING INTERVIEW Faculty Member 3 - 03-005 (3)

Document Text:

1: *DEBRIEFING INTERVIEW Faculty Member 3 - 03-005 (3)

2: *K: Ann Kelson
3: *S: Faculty member

4: *HP1 - SUMMARY OF CASE EVIDENCE
5: K: The first thing is if you would please just give me about a minute case summary with your impressions and plan at the end of that.
6: S: OK. Patient is a 35-year-old white female with a past medical history of asthma who comes in today with a two day headache.
7: It's the worst and longest headache she's had in a long time,
8: although she gets occasional headaches maybe once a month.
9: This one started with her period,
10: it's over her left eye.
11: It started off very severe with some nausea and vomiting.
12: It is a little better now.
13: She's still a little nauseous,
14: but she hasn't had any relief with taking Advil.
15: She also did some heavy lifting a few days ago
16: and has some neck strain type symptoms as well.
17: In addition to that she has had some dizziness and fatigue for the last month, for which she doesn't have a diagnosis.
18: She doesn't smoke or drink.
19: No alcohol.
20: No triggering factors that she can really think of besides her period,
21: although she doesn't get a headache routinely with that.
22: On physical exam, here physical exam was basically normal
23: though one thing I didn't go (into) was orthostatics to see if I could reproduce her dizziness,
24: but her funduscopic and eye exams are normal.
25: Her HEENT is basically normal
26: and her neurologic exam is normal as well.

27: *HP5 WORKING DIAGNOSIS
28: My assessment is that it sounds like a migrainous/tension headache, possibly exacerbated

by her menstrual cycle.
29: Although this patient perceives it as severe,
30: I'm not concerned that this is any kind of malignant etiology for her headache.

31: *HP8 FOLLOWUP
32: I think that if she continues to take some nonsteroidal
33: this headache will resolve.
34: I want her to keep a headache diary in case these headaches become more frequent,
35: in which case then I would do some more investigation
36: but I don't think I'd do any more right now.

37: *HP6 LOOSE ENDS
38: I'm a little concerned about this tiredness and this dizziness,
39: and I think I would order some labs to start working that up.
40: I'm interested in her thyroid function, B12, Folate function to see if this is some sort of a neurologic problem secondary to one of those two diagnoses.
41: I'm also interested in getting a CBC to make sure that she hasn't become anemic as a cause for her fatigue and her dizziness.

42: *HP2 - DIFFERENTIAL DIAGNOSIS
43: K: OK. Great. And your differential you've given me pretty much,

44: *HP7 CONFIDENCE RATING
45: but can you rank order those
46: or did you give them to me in rank order?
47: S: Well her main problem she's here for is her headache.
48: There are some migraine plus some tension headache components,
49: but basically I don't find anything when I'm talking to her or examining her that makes me think that it would be anything more than that at this point.
50: She does have a neck strain.
51: I don't really have a differential for that.
52: She knows why that happened.
53: She was doing heavy lifting.
54: The fatigue and the dizziness are kind of grouped together
55: because they started together,
56: and I think it could be a vitamin deficiency or anemia.
57: Then there's the question of some numbness and tingling of her legs sometimes,
58: maybe there is a neurologic component that is going with the tiredness and fatigue,

59: *HP8 - FOLLOWUP
60: and I would do some testing of her thyroid and her vitamins that can effect the neurologic symptoms to try and figure out about that.
61: K: That's the B12 and the folate.
62: OK. I think you gave me the findings that you were correlating with.

63: *HP5 WORKING DIAGNOSIS
64: So your primary working diagnosis for her complaint is the migraine and tension,

65: *HP8 - FOLLOWUP
66: and that you are going to start out with NSAID I think you said?
67: S: Yes.

68: *HP6 - IDENTIFY LOOSE ENDS
69: K: In your mind are there any aspects of the case at this point that you can't account for?
70: S: She does have the tiredness and dizziness,
71: and I don't know why she has those.
72: K: But you got that in your workup.
73: S: So anything else that sort of really confuses me that I don't know where I'm going with?
74: K: Yes.
75: S: I don't think so.

76: *HP7 - RATE CERTAINTY OF DIAGNOSTIC HYPOTHESES
77: K: OK. At this point, before you get the labs that you ordered, on a scale of 1-5 with 5 being absolutely certain and 1 being not at all sure, what is your confidence of your diagnosis at this point?
78: S: My diagnosis of headache I would say 4 to 5.
79: In regards to why I think she has the fatigue and dizziness, I would say I most likely think that she has developed an anemia,
80: but I would say I'm only about a 3 on that.

81: *LP1 PREFERRED DIAGNOSIS AFTER REVIEWING LAB RESULTS
82: K: OK. Thank you. Now you ordered.
83: S: I think I ordered a CBC, TSH, B12, and a Folate.
84: K: OK. Here is the CBC, TSH. Can you just talk while you're looking at these.
85: S: Sure.
86: Well she has polycythemia which means her hemoglobin and hematocrit are above normal.
87: Her MCV is normal.
88: Her platelet count is higher than normal.
89: The differential eosinophils are slightly high on her white blood cell count.
90: I'm kind of surprised by these findings.
91: It certainly makes me think of a different differential for all of her symptoms.
92: Possibly even maybe her headache,
93: although I think her headache could still be outside of what these results might indicate.
94: I think this TSH result is normal.
95: With a high hemoglobin and hematocrit, what I think about is dehydration,
96: although there's really no reason why I would think that this patient would be dehydrated.
97: If I could do a physical examination maneuver
98: I'd do orthostatic blood pressures to try to figure that out,
99: but the other diagnosis is polycythemia vera which is a problem with the bone marrow producing too many red blood cells.
100: It can be accompanied by overproduction of other cells like the platelets.
101: She may have a bone marrow based problem that is causing the results on this CBC,
102: and patients who have that can have some symptoms.
103: I'm not sure if fatigue is one of them.
104: Dizziness might be one of them.
105: I guess what is more troubling to me is that I'm not sure why she would have developed this problem,
106: it's pretty common in smokers and in older people
107: but she is younger than most people I would expect to have a problem like this.
108: K: So it seems a bit out of sink.
109: S: Yes, this doesn't fit very well with this patient.

110: *LP3 VIABLE ALTERNATIVE DIAGNOSES
111: K: Any alternative diagnosis.
112: You seem to be leaning towards polycythemia vera.
113: S: Yes.
114: K: But, other things come to mind?
115: S: Well because she has two things.
116: The red cells and the platelets are elevated.
117: That kind of makes me lean towards some kind of bone marrow problem
118: and the one that would be the most common to cause both of them is the polycythemia vera.
119: I suppose there are other bone marrow related diseases like myelodysplastic syndrome, that might be the cause of this too,
120: although I think that would be even more unlikely in someone that is her age.
121: I suppose it's also possible that she could be taking something that would elevate these numbers,
122: but I think that would be very very unlikely.
123: If I saw this like in an athlete or someone like that,
124: I might think that maybe they were taking Epogen or something like that.
125: I think that would be really unlikely in this patient.
126: I'm trying to think if maybe this could have been a congenital problem and her blood count has always looked like this,
127: but I'm not familiar with any syndromes that cause this chronically
128: and I would think that at her age she would have been tested and this would have already been found out.
129: I guess there are some malignancies that might as an off shoot of the malignancy cause a problem like this,
130: like a renal cell malignancy might lead to overproduction of Epogen that would lead to increased hematocrit and increased platelet count.
131: That could possibly be an avenue that I would have to do some more workup on.
132: At this point I would be thinking maybe bone marrow or maybe some cytogenic studies on her red blood cells to arrive at a better conclusion of what this is.
133: Possibly testing her urine for red blood cells
134: or doing like a CT of the abdomen to rule out a problem with her kidneys, that might be causing something like this.

135: LP3 PREFERRED DIAGNOSIS VS. ALTERNATIVES
136: K: So now as you've talked through this, your preferred diagnosis at this point, what is your #1, #2?
137: Where are you?
138: S: I'm still not sure I can relate this to her headache,
139: although patients who have a high red cell count can be hypercoagulable
140: so I suppose she could have like a blood clot that could be causing her headache.
141: Without a neurologic deficit I still think that's kind of unlikely.
142: So I'm not sure I can connect this with her headache,
143: so I'm not sure I'd really change my mind about what's causing her headache.
144: But obviously she has an additional problem that I didn't know after examining her,
145: which is this polycythemia.
146: She could either have it secondary to a bone marrow problem with overproduction,
147: or possibly secondary to malignancy.
148: The other thing is that if you are hypoxic chronically
149: you can develop a high red blood cell count,
150: but she doesn't carry any diagnosis of severe lung disease.

151: She has asthma,
152: but she seems to treat it very sporadically
153: so it doesn't seem that she would be hypoxic enough to have a count like this.
154: I think I would discount that from my differential.
155: K: So you are at polycythemia vera or malignancy related renal?
156: S: Or malignancy related, right.
157: K: In terms of your confidence level, again with 5 being absolutely certain and 1 being not at all sure, where would you put-?
158: S: Well, I'm sure she has polycythemia,
159: I mean obviously she has polycythemia.
160: I might consider, just because I'm sort of surprised at this lab, doing it over again just to make sure.
161: But, if I got some more results
162: then I would say I'm very confident that she has polycythemia.
163: I guess I would say 3 or 4, that-,

164: *LP4 LAB INFORMATION CONFIRMING HYPOTHESIS
165: I would guess that this is polycythemia vera because of the increased platelet count.
166: But, because of some of her constitutional symptoms that I'm not sure could be related to polycythemia vera,
167: I would also have to say about a 3 on a possible malignancy.
168: I'm not sure,
169: I guess I'd put polycythemia vera if I had to bet on one that's the one, but not by much.

170: *F26 PATHOPHYSIOLOGICAL MECHANISM
171: K: OK. In terms of the polycythemia vera, your sort of slightly #1, what is the path of physiology that would produce these findings?
172: S: Well, those patients have an increased production of their red blood cells
173: and it's I think because of a stem cell activation that is almost on the lines of a malignancy although it doesn't spread,
174: so it doesn't really fit the definition of malignancy,
175: so it's a stem cell defect that causes increase of these red blood cells to the point where patients can have clots because of the hyperviscosity of their serum.
176: They can get symptoms based on that pathology.
177: Again, it is sometimes seen with essential thrombocytosis which is the increased platelet count,
178: so you could tie those two things together with her.
179: Again, being sort of a stem cell bone marrow overproduction kind of problem.
180: K: Can you go on and just discuss what would be the normal production of red cells, what would be the mechanism for the normal production.
181: S: The normal production of red cells starts with the bone marrow with triggered-,
182: it is sort of feedback mechanism,
183: it starts with the Epogen
184: so if you develop an anemia
185: your Epogen, which is a hormone produced by the kidneys, would increase and stimulate your bone marrow to make more reticulocytes, which are the beginnings of red blood cells
186: that would then get matured in the bone marrow and pushed out in the form of red blood cells, which last for like 3 months in the body.
187: What happens with polycythemia vera is that there is not an overproduction of Epogen
188: but the stem cells and the reticulocytes are overproduced
189: because of an essential problem with the cells in the bone marrow that are producing them,

190: so you get more
191: and probably, although I'm not sure, you probably have a low Epogen level
192: because there would be no reason for Epogen to try to stimulate more production
193: since there is already overproduction.
194: K: So the Epogen is necessary for maturation or not?
195: S: I don't think so,
196: because even in patients who don't make a lot of Epogen because they have a kidney disorder, their red cells are still mature
197: there just is not enough of them,
198: so I think the Epogen is important in triggering the production of the red cells
199: but not necessarily the maturation in the bone marrow.
200: K: So at what point would you say the Epogen kicks in, in terms from stem cell to true blood cell?
201: S: I would say towards the stem cell,
202: like early on in the formation of the red blood cells,
203: but that's not something I'm real sure of.
204: K: So you are speculating right now?
205: S: Right.

206: *LP6 - MANAGEMENT PLAN FOR PATIENT
207: K: OK. Now that we know what we know what is your management plan for this patient?
208: S: Well, if I could confirm that she has polycythemia vera
209: and there are some specific blood tests,
210: I think you can do a red blood cell mass, or bone marrow biopsy with some cytogenic studies you can do to confirm your diagnosis.
211: If she does have polycythemia vera
212: one thing that is done is patients get multiple blood draws, (PHLEBOTOMY)
213: I'm having a blank.
214: Anyway multiple blood draws to try to just extract the extra red blood cells,
215: what is the word for people who go around and draw blood from people,
216: I am completely blanking on the word,
217: but anyway they can get therapy in that way.
218: There are some drugs I think that work like-,
219: I want to say there are some drugs that can suppress the production of red blood cells or increase their lysis
220: so you don't have as many in your system,
221: I want to say Hydroxyzine but I would have to, Hydroxyurea, that I think might help in this situation.
222: I also think that because she also has high platelets, aspirin therapy might be helpful in preventing any kind of hypercoagulable morbidity.
223: I also think that I would check and make sure she wasn't hypoxic.
224: Maybe I would have her wear a oxygen saturation monitor through the day and through the night to make sure she wasn't hypoxic to the point where you might develop a high red blood cell count.
225: I think it's unlikely examining her,
226: but I think I would check that maybe even before I went and did a bone marrow or those more extensive studies on her blood
227: because that would be cheap and pretty easy to do.
228: Then in regards to malignancy, I think I already talked about I would probably get a UA
229: and I might even be convinced to get something like a CT or renal ultrasound just to make sure there wasn't a renal mass that might be causing a problem like this.

230: *F1 COMPARE "EXPERT" AND SUBJECT SUBJECTIVE SECTIONS

231: K: OK. Good. What I need for you to do next is to look at your SOAP note

232: and compare it with the SOAP note written by the attending who treated this patient.

233: Just talk aloud while you are looking at those two.

234: S: OK. Well the first thing that I can say is that it seems like the attending is writing a little bit more by quoting what the patient says.

235: K: In terms of the findings?

236: S: Instead of interpreting it, right.

237: K: Any difference in the findings?

238: S: No. This attending writes down the finding that she is itchy

239: and I found out about that

240: but that is something that I did not put,

241: I forgot to write that down.

242: Past medical history.

243: K: Does that make a difference?

244: S: It is,

245: because when she said that I thought there's another thing that kind of seems like maybe there is something going on.

246: I did think it was kind of significant when she told me that

247: but I forgot to write it down.

248: Then on past medical history there are a few things,

249: the irritable bowel syndrome which I honestly didn't write down because I guess in terms of this problem I was focusing on,

250: even though I elicited it I think I kind of put it towards the side.

251: I didn't find out about the stress related depression

252: so that's something that I didn't elicit from the patient.

253: This a little more specific in a couple areas than mine, like family history.

254: I said negative for chronic diseases

255: and this one puts down the two diseases that the patient did mention.

256: I guess I would say this note is a little more inclusive of some of the things that, since I didn't feel they were very relevant to the patient's main complaint I didn't mention.

257: *F2 RECONSIDER DIAGNOSIS

258: K: OK. Is there anything is what you see in the attending's SOAP note that would influence your diagnosis at the point?

259: S: I think maybe the only thing was that she did take Celexa 5 months ago because she was depressed.

260: K: OK.

261: S: You know when people are tired and dizzy sometimes on the differential is that they are just kind of depressed or somaticizing, which would be more common in patients who are depressed.

262: That would be something that I would put kind of on the bottom of my list.

263: Knowing that she had a problem with it in the past might make it a little more significant to me,

264: although I don't think it's extremely significant

265: or I probably would have asked her about it.

266: Actually when she was sort of just saying yeah I'm also dizzy,

267: I'm also tired, yeah

268: also my skin itches,

269: sometimes my legs turn numb,

270: the thought of maybe she's just one of those people who have a lot of complaints and it

doesn't really add up to something kind of flashed through my mind,
271: so I think maybe if I didn't have a time limit or something
272: I might have asked about stress/depression.
273: It kind of occurred to me while I was talking to her
274: but I decided not to ask her about it.

275: *F4 COMPARE "EXPERT" AND SUBJECT OBJECTIVE SECTIONS
276: K: OK. What about the physical exam objective findings?
277: S: This exam is a little more complete.
278: I sort of did something a little more focused.

279: *F7 SHOW "EXPERT" AND SUBJECT ASSESSMENT SECTIONS
280: K: Any new information there,

281: *F8 RECONSIDER ASSESSMENT
282: anything that would influence your differential?
283: S: I don't think so, no.
284: The headache is sort of exactly what I thought.
285: The fatigue and weakness, and they talk about,
286: he lists all the irritable bowel syndrome and the depression which I didn't list
287: because my assessment I think was more focused on the stuff she complained of today,
288: so it's a little more complete there.
289: But, it covers the same things.
290: One thing that is not in this note that I really got from the patient was the postural nature of her dizziness.
291: This just kind of says that she's lightheaded
292: and this physician's subjective data also doesn't sort of get that postural component to her dizziness, which I think is really important.

293: *F9 COMPARE "EXPERT" AND SUBJECT PLAN SECTIONS
294: K: OK. The plan.
295: S: About the same stuff that I said.
296: I think I was also a little more concerned that there might be something with this postural dizziness,
297: I'm a little more concerned that there might be something going on in regards to peripheral neuropathy or neurologic problem,
298: so those things are present in my plan that aren't present here.
299: But, about her main complaint I think we both thought the same thing.

300: *F15 CONFIDENCE IN WORKING DIAGNOSIS
301: K: At this point how confident are you of your working diagnosis?
302: S: That she has a migraine tension type of headache.
303: K: Given the labs that you see?
304: S: Given the labs I still think I'm pretty confident that that's the problem,
305: so I would still say a 4.
306: K: On the migraine tension headache?
307: S: On the migraine tension headache component,
308: but obviously there is another problem here
309: and could somebody who has a problem with high red blood cell count have a hyperviscosity
310: and have a blood clot that is causing their headache,

311: it is possible but again with her normal neurologic exam I really don't think so.
312: I would still say I'm pretty confident that this headache is maybe outside of the other thing that I found out about from her labs.

313: *F16 COMPARE ASSESSMENT TO ATTENDING PHYSICIAN'S ASSESSMENT AND PLAN AFTER REVIEWING CBC AND DIFFERENTIAL
314: K: Now I'm going to let you look at the followup to the original attendings SOAP note
315: and just-, you've seen those labs, your reaction?
316: S: Phlebotomy, that's the word.
317: Sometimes you just can't.
318: So silly.
319: It's kind of what I find.
320: K: That's the direction you were going?
321: S: Yeah.
322: K: OK great.
323: Thank you very much.
324: Now that we are at the end of the protocol lets go back and if you can just give us some feedback