The Use of Hints as a Tutorial Tactic

Gregory D. Hume[1]
219-464-5156
ghume@exodus.valpo.edu

Joel A. Michael[2]
312-942-6462
jmichael@steve.iit.edu

Allen A. Rovick[2]
312-942-6567
aar@steve.iit.edu

Martha W. Evens[1]
312-567-5153
mwe@schur.math.nwu.edu

[1]Department of Computer Science
Illinois Institute of Technology
10 West 31st Street
Chicago, IL 60616

[2]Department of Physiology
Rush Medical College
1750 W. Harrison
Chicago, IL 60612

Abstract

Hints are a useful and common pedagogical tactic, particularly in one-on-one tutoring sessions. Hints can serve: (1) to activate otherwise inert knowledge making possible its recall, or (2) to stimulate the generation of inferences required to complete a task using knowledge thought to be available to the student. We report on the analysis of one-on-one tutoring sessions conducted by two tutors using a computer system to capture the dialogue. Hints either explicitly convey information to the student or they point to information presumed to be available to the student. We have identified at least 10 different forms of hints used by our tutors. The two tutors differ in the total number of hints they generate and in the prevalence of hints of different types. Our results are being applied to the design of an intelligent tutoring system (ITS) with a natural language interface.

This work was supported by the Cognitive Science Program, Office of Naval Research under Grant N00014-89-J-1952, Grant Authority Identification Number NR4422554 to the Illinois Institute of Technology and Grant N00014-91-J-1622, Grant Authorization Identification Number AA1711319 to Rush Medical College. The content does not reflect the position or policy of the government and no official endorsement should be inferred.

Introduction

It is now recognized that students actively confronting information have better access to it and are better able to use it than students simply receiving it passively (Shuell, 1986). One common teaching paradigm known to be effective is one-on-one tutoring (Bloom, 1984). Tutoring sessions that allow mixed initiatives provide opportunities: (1) for students to be active and (2) for tutors to keep the students focused on the current lesson. Hinting is a tactic that encourages active thinking structured within guidelines dictated by the tutor. Hints function by activating otherwise inert knowledge thus allowing that knowledge to be used in the current task (Bransford et al., 1989). This paper describes a study of hinting in human tutoring sessions in the domain of cardiovascular physiology. This study is intended to contribute to the development of a strategy for using hints in an ITS with a natural language interface.

The human cardiovascular system maintains a more or less constant blood pressure in the face of various perturbations to the system. It does this

through the baroreceptor reflex, a negative feedback system. Disturbances to mean arterial pressure (MAP) are sensed by the baroreceptors (BR) and the central nervous system (CNS) uses the information provided to generate a sequence of responses (changes in other parameters such as total peripheral resistance - TPR, cardiac output - CO, or right atrial pressure - RAP) to reverse the effect of the original disturbance.

The primary goals for medical students studying the baroreceptor reflex are to: (1) acquire an adequate and robust declarative knowledge base, (2) internalize a mental model of the system, and (3) develop a problem solving algorithm that will produce correct qualitative predictions about the responses of the system to disturbances. These goals are achieved through attendance at lectures, reading of textbooks, and practice with a simulation of the system (CIRCSIM; Rovick and Michael, 1992).

We are currently developing CIRCSIM-Tutor (Kim et al., 1989), an ITS with a natural language interface (Chang et al., 1992; Seu et al., 1991), at the Illinois Institute of Technology and Rush Medical College. The current working version of the program allows students to make predictions and provides relatively unsophisticated tutoring about the errors that are made. An enhanced version is under development and will incorporate a robust student modelling module (Hume 1992), a richer, more complete knowledge base (Khuwaja et al,. 1992), and a more sophisticated tutor able to use a variety of tactics to address the students' underlying misconceptions that cause the prediction errors. One such tactic to be employed is hinting. Our expert tutors (JAM and AAR) use hints often in one-on-one tutoring. We set out to understand this process better in the hopes of simulating it in our system.

Methods

Nine tutoring sessions were conducted (four by JAM, five by AAR) with first year medical students. The students were presented with a description of a perturbation to the cardiovascular system (e.g., administration of a drug that affects blood vessels) and were asked to make qualitative predictions about the responses of the baroreceptor reflex. The tutor then engaged the students in an interactive dialogue aimed at correcting the underlying misconceptions or lack of knowledge that led to errors in problem solving and errors in making predictions. During each two hour session the students dealt with two perturbations.

During the sessions, student and tutor (in different rooms) communicate with each other using PCs and a program called CDS (Li et al., 1992). The dialogue was stored on the tutors' hard drive and transcripts were prepared with a second program that numbered the turns and lines etc. The tutors as well as other members of the CIRCSIM-Tutor team then analyzed the transcripts to identify and categorize the hints that had been generated. Excerpts of these transcripts presented in this paper are unedited except to correct typographical and spelling errors.

Analysis

A hint is a rhetorical device that is intended to either: (1) provide the student with a piece of information that the tutor hopes will stimulate the student's recall of the facts needed to answer a question, or (2) provide a piece of information that can facilitate the student's making an inference that is needed to arrive at an answer to a question or the prediction of system behavior.

---

t-104-3: What's the relationship between CO and RAP?

s-105-1: I don't know

t-106-1: When CO decreases, as it did in this case, what would that do to the volume of blood in the venous (central) compartment?

s-107-1: It would cause it to increase

t-108-1: And how would that affect RAP?

s-109-1: It would cause it to increase

t-110-1: Absolutely.

Figure 1. An example of a hint.

Figure 1 contains an example of one kind of hint found in the transcripts of our tutoring sessions. First, the tutor asks a question [line 104] and finds that the student can not provide an answer [line 105]. In response to this, the tutor asks a question [line 106] that actually provides information about a part of the physiological relationship not remembered, or not known, by the student. The student then correctly answers *this* question [line 107]. Having been prompted by this exchange, the student is now able to answer the tutor's next question [line 108]. The hint provided in line 106 thus enables the student to reason to a correct answer to the originally stated question [line 104].

An analysis of the transcripts suggests that hints can be categorized by the manner in which students are prompted with the information they need to proceed with their problem solving. Some hints directly convey information to the students (ci-hints). Other hints point to information but do not explicitly convey information to the student (pt-hint). The hint in Figure 2 is a ci-hint; the student is given complete piece of information [line 18]. Hints of this category, in many cases, give the student a small piece of the knowledge base. A pt-hint points to the place in the knowledge base where the pertinent information can be found. This type of hint generally requires a greater degree of cognitive activity by the student. First, the student must understand what the tutor said. For example, in Figure 1 [line 16] the student must be able to generate a chain of causal relationships linking CO and the venous compartment. Then the student must understand the relevance of that information to the question at hand [line 104]. In this example the tutor pointed to a place in the knowledge base where relevant information could be found.

---

t-16-2: Tell me which variable in the predictions table you think will be affected first by the drug.

s-17-1: Initially, MAP, TPR, and CO

t-18-1: If the alpha receptors are found ONLY on the blood vessels, then when the drug is administered, what variable will be changed first?

Figure 2. An example of a ci-hint simultaneously providing a negative acknowledgement.

Hints in each category can be given in a number of identifiable forms. All of the hints present in the transcripts were counted and categorized. The results are presented in Table 1. Ci-hints can be found in three general forms: (1) explanation followed by a question, (2) summary followed by a question and (3) some combination of explanation and summary followed by a question. In all forms, the question may be implied or explicitly stated. Figure 2 [line 18] is an example of an explanation followed by an explicitly stated question.

A summary differs from an explanation in that its content is primarily a review of previous dialogue. Figure 3 provides an example of a hint where the tutor provides an explanation [line 124-2 through 124-5], a summary [line 124-6] and then implies that the student should answer a question not explicitly stated [line 124-7].

The form of pt-hints can vary from a direct question ("What are the neurally controlled variables?") to a declarative statement ("You have not predicted RAP yet.") to an imperative statement ("Remember the definition of DR"). The tutor assumes the student understands the current problem or question even if there is no explicit question posed.

There are two forms of pt-hints that provide specific information about the nature of the error being corrected. The first form is a partial acknowledgment of an answer (positive or negative). Figure 4 contains an example of this. The single word in line 192 implies that the answer was not completely correct, and it also suggests that the student should come up with more of the answer.

The second form is when the tutor summarizes incorrect responses of the student or talks about the implications of the student's response with some

---

t-124-1: Let's try again.
t-124-2: MAP= CO x TPR.
t-124-3: CO doesn't change.
t-124-4: TPR increases.
t-124-5: MAP should increase by that logic.
t-124-6: But you correctly said that the reflex doesn't completely correct MAP.
t-124-7: So?

Figure 3. A ci-hint in the form of explanation/summary/implied question.

t-190-1: What parameters does it ordinarily affect?
t-190-2: List them.

s-191-1: HR, TPR
t-192-1: And?

s-193-1: CONTRACTILITY
t-194-1: Yes.

Figure 4. A pt-hint in the form of a partial acknowledgement.

implication that the student was in error. The intent of the tutor is that the student will recognize the error in logic.

Another form of the pt-hint category is a question by the tutor used in lieu of directly answering a student question. Again, this requires a sequence of activity by the student. The student must understand the tutor's question, recognize the connection between the tutor's question and the original question and then infer or recall the answer to the original question.

It was observed that some hints appeared to be simultaneously serving other functions. Hints providing an implied negative acknowledgement are one example. In Figure 2 the tutors' response [line 18 - emphasis present in the original transcript] provides some information, the "...ONLY..." in the question, that suggests that the student answer [line 17] was wrong. At the same time, line 18 reminds the student about an important fact with which the student ought to be able to reason to a correct

Category	Session by Number and Tutor									
	AAR 1-5					JAM 6-9				
	1	2	3	4	5	6	7	8	9	Total
A1	2	3	2	0	4	1	1	3	1	17
A2	0	0	1	0	0	0	0	0	0	1
B1	10	6	4	2	5	7	9	4	6	53
B2	3	4	3	1	5	0	0	0	0	16
C1	0	1	2	1	1	0	1	1	0	7
C2	0	0	1	1	0	0	0	0	0	2
D	12	22	8	4	7	9	10	5	7	84
E	0	0	0	0	1	0	0	1	0	2
F	3	1	1	1	6	0	0	0	0	12
G	1	0	0	2	0	1	0	2	1	7
Total	31	37	22	12	29	18	21	16	15	201

Ci-hints:

A1	Summary + question
A2	Summary + implied question
B1	Explanation + question
B2	Explanation + implied question
C1	Explanation/Summary combination + question
C2	Explanation/Summary combination + implied question

Pt-Hints:

D	Question, explicit or implied
E	Tutor replies to student's question with a question
F	Partial acknowledgement (positive or negative)
G	Summary or implications of incorrect student response

Table 1: Distribution of hints from the nine tutoring sessions by category and form.

answer. Hints also simultaneously serve the purpose of providing the tutor with insight into the student's capabilities.

Two conditions must be present for hinting to occur. First, the student must have exhibited some deficiency or error (see [line 105] of Figure 1). Second, the tutor must have some reason to believe that the student is likely to be able to respond positively to the hint. The tutor constantly updates his or her perception of the student's capabilities. In an ITS this process is referred to as student modelling. All of the students solving these problems have been exposed to class lectures and assigned readings and the tutor assumes (at least initially) that each student has sufficient background so that hinting is always attempted at the start of a tutoring session.

There are two conditions, however, when a tutor ceases to use hinting as a tactic. First, the student may consistently display a lack of background information or poor problem solving skills. In this case, the tutor will cease to use hinting in the tutoring session once this deficiency is identified. Second, if repeated hints (usually two) directed at a particular issue are not successful, hinting will stop and the tutor is likely to respond to errors with explanations. Our tutors have found that repeated, unsuccessful hints are frustrating to the student and are likely to impede learning.

Discussion

Our intent has been to study the use of hints by experienced tutors in the hopes of formulating a strategy for using hints in an ITS. We have searched through the literature in education, linguistics and intelligent tutoring and have found only sketchy references to hinting. We have, therefore, attempted to (1) define hints, (2) categorize them by form, intent of tutor and content of information conveyed, and (3) observe when they are used and not used. Table 1 summarizes the total number of hints, in each category and format, over nine tutoring sessions.

An analysis of the transcripts suggests that the most important criterion for identifying an utterance by the tutor as a hint is the tutor's intention to assist a student in arriving at an answer without actually providing the answer. For example, a tutor may pose a question with the sole intention of gathering information about the student's cognitive state. On the other hand, an utterance of the same form may be intended to stimulate recall by the student or to provide enough information to allow the student to make an inference. The tutor's intention was the primary factor considered when identifying hints. The nature of information provided to the student was the primary factor considered when categorizing hints. Some hints supply some portion of complete information (ci-hints) without supply the answer. Other hints only remind the student of certain information to which they should have access (pt-hints). While it is obvious that hints occur when the student has made an error, it is less obvious how the tutor decides that hints are not working and stops using them.

There are a number of questions that naturally follow from this study. What are the rules used by tutors to generate hints? More specifically, how are the content, category and form of hint chosen? The transcripts suggest that the student's cognitive state plays an important role in the generation of hints; a tutor must have some reason to believe that a particular hint may be a useful tactic. Evidence of student deficiencies in certain areas certainly help in the selection of domain knowledge that is presented in a hint. What are the other factors that contribute to the generation of a hint? What causes a tutor to use a pt-hint as opposed to a ci-hint? Why are some hints explicitly stated as questions? In what order are the decisions about content, category and form considered by the tutor? It is reasonable to assume that a human tutor does not consciously address each of the above questions. We will attempt to engage experienced tutors in knowledge engineering activities so that some rules regarding hint generation can be identified.

These transcripts suggest that these two experienced tutors make use of hinting quite differently. JAM never provided ci-hints with implied questions (categories A2, B2 and C2). Also, JAM used pt-hints much less often than did AAR (an average of 9/session vs. 14/session). Our sample is, of course, small, and these numbers may not be statistically significant, but this observation raises more questions about the use of hints. Is one personal style preferable to another or are the differences of style between experienced tutors superfluous?

Another important topic for research deals with the effectiveness of hints. For example, is one type of hint more successful in assisting students than another? Does the success of different types of

hints vary in any systematic way with the cognitive state of the student (how much they know, how well they solve problems)? While it may be possible to count the number of hints that immediately produce a desired result, that statistic ignores important non-tangible considerations. Is the tutor providing hints that are too obvious and is the chain of reasoning too simple? On the other hand, can an obscure hint trigger a desired result after the tutoring session is completed? We will be attempting to answer such questions in future studies.

Conclusion

The use of hints as a tutorial tactic is common, but not yet thoroughly understood. Hinting, we believe, promotes the kind of cognitive activity that leads to meaningful learning. More research is needed to understand how effective hints can be generated. Such research can lead to rules that can be used in an ITS.

References

Bloom, B. S. 1984. The 2 sigma problem: the search for methods of group instruction as effective as one-on-one tutoring. *Educational Researcher* **13**: 4-16.

Bransford, J. D., Vye, N. J., Adams, L. T. and Perfetto, G. A. 1989. Learning skills and the acquisition of knowledge. In A. Lesgold and R. Glaser (Eds.), *Foundations for a psychology of education*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Chang, R.-C., Evens, M., Rovick, A. A., & Michael, J. A. 1992. Surface generation in a tutorial dialogue based on analysis of human tutoring sessions. In *Proceedings of the Fifth Annual IEEE Symposium on Computer-Based Medical Systems*, 554-561. Durham, NC.

Hume, G. 1992. A Dynamic Student Model in a Cardiovascular Intelligent Tutoring System. In *Proceedings of the Fifth Annual IEEE Symposium on Computer-Based Medical Systems*, 370-377. Durham, NC.

Khuwaja, Ramzan A., Evens, Martha W., Rovick, Allen A., & Michael, Joel A. 1992. Knowledge representation for an intelligent tutoring system based on a multilevel causal model. In C. Frasson, G. Gauthier, & G. I. McCalla (Eds.), *Intelligent Tutoring Systems (Proceedings of the Second International Conference, ITS '92*, Montreal, CANADA). Berlin: Springer-Verlag. 217-224.

Kim, N., Evens, M., Michael, J. A., & Rovick, A. A. 1989. CIRCSIM-TUTOR: An intelligent tutoring system for circulatory physiology. In H. Maurer (Ed.), *Computer Assisted Learning (Proceedings of the International Conference on Computer-Assisted Learning)*, 254-256 Dallas, TX). Berlin: Springer-Verlag.

Li, J., Seu, J., Evens, M., Michael, J., & Rovick, A. 1992. Computer dialogue system (CDS): A system for capturing computer-mediated dialogue. *Behavior Research Methods, Instruments, & Computers* **24**: 535-540.

Rovick, A. A., & Michael, J. A. 1992. The predictions table: a tool for assessing students' knowledge. *American Journal of Physiology* **263**: (*Advances in Physiology Education*, **8**), S33-S36.

Seu, J. H., Evens, M., Michael, J., & Rovick, A. 1991. Understanding ill-formed input to an intelligent tutoring system in an LFG framework. In *Proceedings of the Third Midwest Artificial Intelligence and Cognitive Science Society Conference*, 36-40. Carbondale, IL.

Shuell, T. J. 1986. Cognitive conceptions of learning. *Review of Educational Research* **56**:411- 436.