Affective Feedback in a Tutoring System for Procedural Tasks

Dirk Heylen, Maarten Vissers, Rieks op den Akker, and Anton Nijholt

Twente University, Enschede 7500AE, the Netherlands,
`heylen@cs.utwente.nl`

Abstract. We discuss the affective aspects of tutoring dialogues in an ITS -called INES- that helps students to practice nursing tasks using a haptic device and a virtual environment. Special attention is paid to affective control in the tutoring process by means of selecting the appropriate feedback, taking into account elements of the student's character, the harmfulness of errors made, and the emotional effects of errors and feedback. The tutoring system will adjust both the affective language used and the overall teaching tactics.

1 Introduction

Affect control[1] is an important factor in social interaction in general. Sometimes learning is more effective with the help of a personal tutor. But this is very expensive and therefore it could be useful to develop intelligent personal tutoring systems that help students learn either a conceptual theory, to solve theoretical or practical problems or to master a practical task. In this paper we discuss affect control in a tutoring system called INES that helps nursing students in practicing tasks such as giving a patient a subcutaneous injection. In nursing schools students practice this task with a fake plastic arm. A teacher is present who gives advice and feedback. This is very time consuming and expensive.

With the INES system students can practice the tasks on the computer using a haptic device, a Phantom, to give an injection in the arm of a virtual patient. This can be seen in the picture in Fig. 1. The tutor is visualized by a talking head that can display some emotion expressions.[2]

Our aim is to make an ITS that builds on the psychology of affect and emotion to make the learning process more efficient. What should the tutor say or do in a particular situation to optimize the learning curve?

The part of the ITS that we will focus on in this paper[3] is the instruction module that decides on the sequence of instructions that will be given (see Fig. 2).

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[1] "People credit themselves and others with specific identities during social encounters. They then engage in physical and mental work so that events create impressions that maintain sentiments attached to their identities, as well as to other categories of action (i.e., behaviors, settings, and personal conditions - emotions included)." From [1].

[2] More about the agent-based architecture of this rather complex multi-modal interaction system can be found in [2].

[3] More information about INES can be found in [3] and [4].

Fig. 1. A picture of a student working with the system.
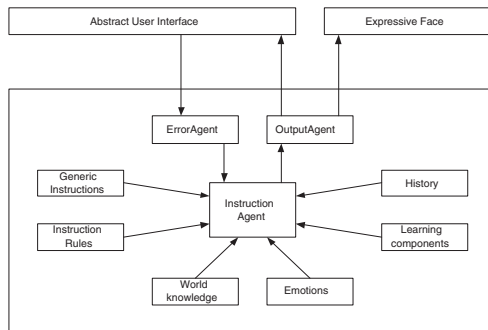
Fig. 2. Overview of the different agents and components in the tutor component.

The module termed Learning Components, decides on what kind of learning component (see [5]) or teaching strategy is taken. For instance, if the Socratic Method is active, the tutor will tend to ask more questions. The choice of Learning Component can be changed dynamically during a tutoring session. The choice is mainly based on the activity level of the student and the particular stage in an exercise. In the current prototype implementation we have considered active student learning, deep explanatory reasoning and affect and motivation as learning components and the Socratic method as a pedagogical strategy.

So-called error-agents provide the instruction module with information about how the student is performing the task. The kind of error students make, the harmfulness of the error, and the number of times a student has made it are the main input to determine the kind of response.

The INES system also contains emotion appraisers. These set the intensity of a few emotion types based on the events that occur. There are two sets of values. One set models the tutor emotions and another set the student emotions. These values are taken into account in determining the nature and the form of the dialogue act that will be performed.

In the following sections we will go into some more detail on how the system works and the considerations that have let us to set up the system in this way. We first present some of the background on tutoring which we used in our work.

2   Affect in Tutoring

Tutoring situations can be characterized as a social encounter, the goal of which is for a student to learn some task or acquire knowledge with the tutor acting in all kinds of ways to assist the student with this goal. As with about all actions we carry out, our emotional state plays an important part in the selection of our actions and the evaluation of the result. The actions we carry out and their results have an impact on how we feel, in turn. Bales ([6]) systematically observed groups in laboratories and found that a substantial proportion of group interaction is devoted to the socio-emotional issues of expressing affect and dealing with tension. Likewise, the actions of a tutor are also not just restricted to pure instructions but they should also create the right emotional conditions for a student to act. The fact that the tutoring situation is a social encounter means that influencing the emotional state proceeds through social acts with emotion changing potential. For instance, the tutor has the status to judge (criticize or praise) the student for his actions. There are several other interpersonal actions that give rise to affect appraisals. Consider, for instance, the difference between the psychological effect of formulating a task as an order or as a suggestion. The tutor has to steer and motivate the student, know when the student welcomes a hint, etcetera. In general one of the goals that people want to come out of of social interaction is to enhance the self of each actor. The ideal outcome is that the student is proud of his achievements and feels highly estimated by the tutor. The emotional state related to this form of social interaction typically involves elements and variables such as: social rewards, dependence, status, power, and face.

The emotional state of the student contributes a lot to whether a student is motivated or challenged, which are key conditions for certain actions. Curiosity and puzzlement may lead to investigate problems. But also frustration may lead to action, even though it is a more negative affect (see [7]) The tutor can choose to consider taking certain actions to bring about a change in the emotional state. Lepper ([8]) identified four main goals in motivating learners: challenge them, give them confidence, raise their curiosity and make them feel in control. These goals can be achieved by means of various tactics. The student can be challenged by selecting appropriately difficult tasks, or by having the difficulty emphasized or by having some kind of competition set up. Confidence can be boosted by maximizing success directly (praising) or indirectly ('it was quite a difficult task, you managed to do'). Curiosity is typically raised in Socratic methods when the student is asked to ponder many questions. The tutor can decide to leave the initiative to the student or offer options that suggest the student can make choices and thereby influence the student's feeling of being in control.

Lepper's goals have been taken into account in our system in the choice of learning component or teaching strategy (Socratic methods, active student learning, using deep explanatory reasoning, etcetera).

Affective parameters in tutoring dialogues not only concern the choice of conversational act and the overall tutoring strategy, but also the kind of language that is used. In tutoring dialogues we see a number of specific dialogue acts, characteristic of tutoring. They make tutoring conversations different from other types of conversations, say information dialogues and task dialogues. Some of the dialogue acts are special for affect control; either for controlling the atmosphere of the conversation or for controlling the motivational state of the student. This is an immediate consequence of the specific roles, goals and tasks the participants have in a tutorial conversation. The student's goal is to learn something, to solve a theoretical problem or to master a practical task. The task of the tutor is to encourage the student's active learning behavior by guiding him, giving hints, asking questions to stimulate the student to reflect on what he is doing, carefully avoiding to give away the solution to the problem. Types of responses that are completely unsatisfactory in other types of conversations are common in tutorial dialogue. Tutorial dialogue shows extensive use of acknowledgement acts and accept acts by the tutor - showing his understanding and encouragement - and a lack of explicit signals from the student's side that he will cooperate. In case the learner has to master a complex practical task, the tutor has to follow the students actions, to see whether he's doing the subtasks in a correct order and whether he's doing the subtasks well. The tutor has to evaluate the student's actions and give appropriate feedback, positive or negative, dependent on the student, and the complexity of the task. When the student makes an error he can choose to interrupt the student or to leave him and wait until the student finds out himself. The tutor has to see whether the student makes enough progress in learning the task, and, if not, to figure out what are the causes of the mistakes he makes. In all of these tasks the tutor should have a good feeling for the affective and motivational state of the student. The tutoring systems need rather involved reasoning and planning mechanisms for realizing all these functions.

In the following section we will look in more detail how the INES system deals with providing the right kind of instructions.

3   Tutoring Dialogues and Tutoring Strategies in INES

Affect in INES is considered from various angles and on different levels.

- The emotional state of the student will be modelled by an event appraisal system.
- The emotional state of the tutor is modelled as well, including values for emotions and parameters such as satisfaction, disappointment, and surprise.
- The dialogue acts come in different forms, with variation in affective values.
- Various affective parameters are used in determining which tutoring strategy to use and which instructional act to perform (sympathizing or non-sympathizing feedback, motivation, explanation, steering, etcetera).

The main elements that go into calculating the emotional state of the tutor are: the level of activity of the student, the difficulty of the task, the history of the student (how well he/she did in previous tasks), the number of errors made, the severity of the error. For the tutor model we have limited our implementation to four values, representing the emotions *joy, distress, happy-for* and *sorry-for*. With respect to the student model, there are four emotional categories that affect the selection of the kind and form of instruction. These are *anxiety - confidence* and *dispirited - enthusiasm*. In the current prototype these remain fixed during a session and thus act more like personality profiles.

It seems less important that tutors show their own real emotions. But we think that tutors should show empathy with the students and understand how their emotional state is affected by what the tutors do. In order to make a good guess of how the student's affective system reacts in particular situations the tutor also has to have some idea of the character of the student: introverted, self-critical, extraverted, anxious to do something wrong, or self-confident. For a believable tutor agent it is necessary that he monitors the emotional and motivational state of the student. Recognition of the affective and emotional state of the student is a difficult task for a tutoring system. It assumes automatic affect recognition in text and prosodic properties of speech, in facial expressions and in other aspects of non-verbal behavior. Moreover, we need ways to automatically detect features to induce the state of concentration, motivation and engagement of the student. We have started to investigate some of these techniques. Instead of trying to determine the emotions of the real student by means of affective computing techniques, the ITS could also builds up a model of the student emotions by using appraisal rules. This is the route that we have pursued for the current version.

In working with INES, students start by choosing an exercise to perform. The system uses descriptions of exercises that contain information about the different subtasks involved (partially ordered), the kinds of errors, pointers to error-agents that can detect the errors, error messages, and steering acts, explanations, hints, questions and answers. Many of are these are used to specify the precise output of INES. The output consists of text messages, spoken output, expressions on a 3D face, and haptic feedback through the phantom. The main conversational and tutoring functions that have to be performed are: make conversation (welcome, introduction, closing), give instruction, set a task, answer questions, ask a question, provide support, give feedback, explain, evaluate, motivate, expect, steering.

The task of the tutor is mainly to guide the student by monitoring his behaviors and to give feedback. When the student performs these tasks, special dedicated error agents monitor the actions of the students and the order in which they are performed. When these agents observe an error (wrong angle pitch during injection, movements too fast, etc.) they send an error report to the instruction agent that evaluates these reports and decides upon a responding action.

The type of action and the manner in which it is executed is determined by a number of factors. The tutor decides on a specific tutoring strategy or learning component (which might be changed in the course of the lesson).

The selection of the strategy depends on the activity level of the student. Three levels are introduced on which the tutor can operate. The idea is that there is congruence between the student's self steering and the tutor's external steering. Thus, on level 1, when the student isn't active at all, fixed external steering is used. The tutor dynamically switches between the different levels, taking into account the performance of the student. The idea of using different levels of activity is based on an algorithm in [9], which determines what kind of hint (with what kind of activity) should be given taken into account the student's current and previous answers, the number of wrong answers, the previous hints produced and number of hints produced.

The choice of strategy influences the kinds of actions that are performed and the sequence in which they are performed. For instance, when the Socratic method is active, the tutor will choose to ask a lot of questions. We are interested in having our tutoring system teach the students certain practical skills with an insight into the reasons for doing tasks in a specific way. An important part of tutoring sessions is therefore to let the students practice some task. In this case the tutor simply observes what the students does and provides feedback. Ideally, the student should be active and self-motivated to practice the tasks. Because the typical exercises involve practicing a task, the error-agents form an important component of the system. They observe the student's actions, diagnose them and report to the instruction-agent: the multi-modal dialogue manager or brain behind the ITS that determines the sequence of instructions. For instance, the sequence ⟨feedback, motivation, support⟩. This is called the teaching task *support_tt* and is typically instantiated in case of an haptic error. For each of the instructions, called dialogue tasks, a dialogue function will have to be chosen. These are more specific instances of the dialogue tasks. For support there are functions such as 'hint correct answer', 'hint error emphasize' and 'hint error diagnosis'. For each dialogue function there are several specific dialogue acts. These can be verbal or nonverbal messages (head nods, for instance), or feedback given through the haptic device.

Figure 5, at the end of this paper shows a list of dialogue tasks and dialogue functions that we identified for a teacher tutoring procedural tasks. Each of the functions can only be applied when a number of preconditions are satisfied. In the prototype a selection of the dialogue tasks has been implemented. These are marked with an asterix. We have left out tasks such as conversation (used for welcoming, introductions and closings), questions and answers.

4   Some Initial Tests

Several types of tests of the system have been performed but no user evaluation has been carried out so far. We tested the effect of various parameters on the choice of dialog acts by letting the system respond to the same input with different settings for these parameters. The behavior of the student was simulated according to specific scenario's. The tests were conducted to see how the tutor's conversational responses and his emotion expression, varies with the settings of a number of parameters in a scenario in which the student repeatedly makes the same error, namely he brings in the needle under an angle that is too wide. The

tests were performed in varying situations in which the following features were controlled.

1. Tutor shows his own emotion or not. Four emotion categories were implemented and tested for their effect on the conversational behavior: *joy, distress, happy-for* and *sorry-for*.
2. The tutor takes the student's emotions into account whether the student is either *confident* or *insecure*.[4]
3. The tutor follows a Socratic learning strategy and stimulates active student learning. The tutor then favors asking questions above giving lengthy explanations.
4. The harmfulness of the error the student makes.

Figures 3 and 4 show a dialogue between the emotional tutor with a confident versus an insecure student, respectively.

Student: Uses an angle that is too wide
Tutor: Shows a negative facial expression (sadness)
Student: Uses an angle that is too wide
Tutor: Not quite. It's okay. Take care of the angle with which you put the needle in.
Student: Uses an angle that is too wide
Tutor: Stop. That's wrong! You shouldn't inject with an angle that is too wide. Try it again.
Student: Uses an angle that is too wide
Tutor: Try again. I will steer you along this time.
Student: Uses an angle that is too wide
Tutor: Decrease the angle.

Fig. 3. The dialogues in the test: between a confident student and an emotional tutor

Student: Uses an angle that is too wide
Tutor: Shows a negative facial expression (sadness)
Student: Uses an angle that is too wide
Tutor: Not quite. You use a wrong angle. Okay, start again.
Student: Uses an angle that is too wide
Tutor: Not quite. It doesn't matter. Take care the angle isn't too wide.
Student: Uses an angle that is too wide
Tutor: Wait a minute, you're in the wrong direction. It's okay. Try to keep an angle of thirty to fourtyfive degrees.
Student: Uses an angle that is too wide
Tutor: Not quite. I will give a demonstration of the task.

Fig. 4. The dialogues in the test: between an insecure student and an emotional tutor

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[4] These states correspond with two quadrant spaces - anxiety vs. confidence and dispirited vs. enthusiasm of Reilly and Kort. ([7]).

Dialogue Task	Dialogue function	Explanation/Example
SUPPORT	HINT-ERROR-DIAGN*	Hint including the error made
		"Take care of a correct angle"
	HINT-ERROR-EMPH*	Hint including the error made
		"Take care of a smaller angle of the needle"
	HINT-CORRECT-ANSWER*	Hint including the correct answer
		"Take care that the angle with which you put
		the needle into the arm is 30 to 45 degrees"
FDB-TURN-TU	FEEDB-ACCEPT*	Accepting feedback
		"That is the correct answer"
	FEEDB-PART-ACCEPT*	Partly accepting feedback
		"Something like that"
	FEEDB-PART-REJECT*	Partly rejecting feedback
		"Not so much that"
	FEEDB-REJECT*	Rejecting feedback
		"That isn't the correct answer"
FDB-TURN-ST	FEEDB-ACKN-BACK*	Acknowledging feedback
		"Uh-huh"
	FEEDB-BACK-QUESTION	Question back
		"Is that right?"
	FEEDB-NON-UNDERST	Non understanding feedback
		"Excuse me?"
	FEEDB-REPEAT	Repeating feedback
		"So your answer is 45 degrees?"
EXPLAIN	ERROR-DIAGN*	Explanation including the error made
		"The error you made has to do with
		the angle in which you put in the needle"
	ERROR-EMPH*	Explanation including the error made
		"You shouldn't bring in the needle with
		such a big angle"
	CORRECT-ANSWER*	Explanation including the correct answer
		"You should bring the needle in
		with an angle of 30 to 45 degrees"
EVALUATE	STUD-EVAL-POS*	Positive evaluation of the performance
		"You did a good job"
	STUD-EVAL-NEG*	Negative evaluation of the performance
		"You didn't do it very well"
	ERROR-ENUM*	Error enumeration
		"You should take care of the angle
		in which the needle is brought in"
	ANSWER-ENUM	Answer enumeration
		"Just remember that the needle should be
		brought in with an angle of 45 degrees"
	EXPECT-LATER	Expectantions for later
		"I expect you to do it right next time"
MOTIVATE	M-WRONG-ANSWER*	Motivate when a wrong answer is given,
		"I'm real sorry" (sympathy)
		"That's all right" (downplayer)
	M-CORRECT-ANSWER*	Motivate when answer correct(enthusiasm)
		"Good job, I knew you could do it."
EXPECT	EXPECT-NOW	Expectations for now
		"It's a difficult task"
EXCLAMATION	EXCLAMATION-NEG*	Negative exclamation
		"How did you get to such a wrong answer!""
STEERING	STEER*	Steering at real-time.
		"Decrease the angle."

Fig. 5. Dialogue tasks and functions

These two dialogue fragments clearly show that setting the parameters differently causes significant differences in the teaching tasks and dialogue functions. In the second case the tutor responds in a more sympathizing way, using more motivational verbal instructions, no exclamations and no total rejection. We have let different people judge the various scenario's (showing them not just how the dialog unfolded but also the facial expressions) and in general the output differs along with what people would expect to change in the various situations. Of course, the dialogue is contrived, because the student keeps making the same error. Also, the prototype uses several responses that may seem a bit awkward or exaggerated. This can be fixed by adjusting the exercise files and is therefore a matter of scripting. We will need to fine-tune one or more exercises before we can carry out further evaluations of the system.

5   Conclusion

We have refined an earlier version of our tutoring system with several modules to account for affective issues during tutoring. The emotional states of students and the tutor are modelled and taken into account in various ways in the tutoring process. The elaborate instruction model is build around pedagogical strategies and learning components (Socratic methods, active student learning, etcetera). The tactics used by the tutoring situation depends to a large extent on the mental state a student is in or should be in. Besides considering the overall strategy, the emotional states also have an effect on the selection of dialogue acts and the precise phrasing.

The system does not recognize the students emotional state in any way. We make some basic assumptions about what we expect the student to feel. These are rules of thumb, for instance, frustration gets bigger when things keep on going wrong. We are currently also investigating ways to determine some aspects of the emotional state of the real student.

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