

Interactive Pedagogical Drama

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ABSTRACT

This paper describes an agent-based approach to realizing interactive pedagogical drama. Characters choose their actions autonomously, while director and cinematographer agents manage the action and its presentation in order to maintain story structure, achieve pedagogical goals, and present the dynamic story to as to achieve the best dramatic effect. Artistic standards must be maintained while permitting substantial variability in story scenario. To achieve these objectives, scripted dialog is deconstructed into elements that are portrayed by agents with emotion models. Learners influence how the drama unfolds by controlling the intentions of one or more characters, who then behave in accordance with those intentions. Interactions between characters create opportunities to move the story in pedagogically useful directions, which the automated director exploits. This approach is realized in the multimedia title *Carmen's Bright IDEAS*, an interactive health intervention designed to improve the problem solving skills of mothers of pediatric cancer patients.

Keywords

Believability; communication, collaboration, and interaction of humans and agents; lifelike qualities; modeling the behavior of other agents; models of emotion, motivation, or personality; synthetic agents

1. INTRODUCTION

People face difficulties in every day life that require sophisticated problem solving skills. Children at school need effective skills to avoid pressure from peers to engage in various unhealthy, risky behaviors. Mothers of very sick children face tremendous emotional, physical and financial strains. For example, the extra demands on their time may cause problems at work or with their other children.

Teaching the skills necessary to cope with these problems is the goal for a style of instruction we call an interactive pedagogical drama, compelling interactive stories that have didactic purpose. In an interactive pedagogical drama, a learner interacts with believable characters in a believable story that the learner empathizes with. In particular, the characters may be facing and

resolving difficulties similar to the learner's, so the learner experiences and learns skills that can be applied to her own problems. The learner's identification with the characters and the believability of their problems are central to the goals of having the learner fully interact with the drama, believe in the efficacy of the skills being employed in it and subsequently apply those skills in her own life. Interaction furthers the learner's involvement and identification with the story by allowing her to tailor the problems being addressed, to determine character's thoughts and emotions, and, more subtly, to tailor how evocative the drama is.

This paper describes an agent-based approach to realizing interactive pedagogical drama. Characters in the drama choose their actions autonomously following directions from the learner and/or a director agent. Director and cinematographer agents manage the action and its presentation in order to maintain story structure, achieve pedagogical goals, and present the dynamic story so as to achieve best dramatic effect. Multimedia presentation makes the story more accessible, particularly for learners with language or literacy problems. The overall goal is to ensure that the resulting presentation is dramatically effective and achieves high artistic and pedagogical standards, while permitting significant learner control and dynamic interaction.

2. OBJECTIVES AND APPROACH

These goals are realized in the multimedia title *Carmen's Bright IDEAS*, an interactive health intervention designed to improve the problem solving skills of mothers of pediatric cancer patients. The pedagogical goal of the title is to teach a specific approach to social decision making and problem solving called Bright IDEAS [22]. "Bright" means having an optimistic attitude that the learner's problems can be solved. Each letter of IDEAS refers to a separate step in the problem solving method: *Identify* a solvable problem, *Develop* possible solutions, *Evaluate* your options, *Act* on your plan and *See* if it worked. Currently the Bright IDEAS method is taught in clinical settings, via a series of one-on-one sessions with trained counselors. The purpose of *Carmen's Bright IDEAS* is to allow mothers to learn more on their own and at times of their own choosing, and rely less on face-to-face counseling sessions.

The creation of any interactive agent-based drama, whether explicitly pedagogical or not, faces several challenges. Fundamentally, good drama requires good story structure, with a strong narrative drive, believable plot, etc. In agent-based drama, that structure must be maintained even though the world is inhabited by self-motivated, improvisational agents. This suggests a need for some form of dynamic direction of the agents [11]. The agent cast that inhabits the stories, as well as their interactions, must be believable [19]. The presentation of this story, its dynamic "filming" (i.e., choice of camera shots) [1] and the appearance of the characters must support this believability and maintain engagement.

However, the introduction of pedagogical objectives poses additional challenges. We seek an open-ended design that allows the learner to explore possible actions, while staying within a pedagogically appropriate “gaming” space. Otherwise, there is no reason to expect that the lessons learned are the lessons that we intend to teach. For example, if agents have their problems miraculously solved for them by aliens, the story might be entertaining but not much positive learning will result. Yet the imposition of any pedagogical constraints on character behavior or plot must not adversely impact believability or the learner's empathy for the characters. This suggests a need for pedagogically aware direction that is also subtly realized.

Interactive drama can be either immersive (where the audience members are themselves playing roles in the drama) or presentational, where the computer interface acts as a proscenium separating action from audience. A number of interactive drama systems, such as Crawford's Erasmatazz [5], have adopted an immersive approach. The work described in this paper, like that of Machado et al. [13], instead adopts a presentational approach. The learner can influence the course of action of the story, but does not directly participate as a story character. There are both clinical and technical reasons for this choice. It allows learners to maintain a degree of separation between themselves and the story; we want the learners to empathize with the characters and help them overcome their problems, but we do not want the learners to have to assume the burden of these problems themselves. It also permits more freedom in story direction and presentation than immersive drama does. Narrative devices such as flashbacks for conveying back-story and cinematic techniques such as close-up camera shots and cross cuts may be used. Presentational drama is a genre that is already familiar to scriptwriters and directors, making it easier for us to enlist their talents. Immersive drama in contrast is more limiting because it restricts the story to a linear time progression and tends to restrict the point of view to that of a single story character.

The story for *Carmen's Bright IDEAS* was developed by a professional scriptwriter, Jonathan Kaplan, in consultation with the clinical professionals who developed and administer the Bright IDEAS method. Instead of focusing first on building believable social agent behaviors [19], we felt that it essential to focus first on the story, to ensure that it was as engaging and effective as possible. However, stories as conceived by storywriters are necessarily linear, and do not immediately lend themselves to nonlinear portrayal. The task of the dramatic direction in *Carmen's Bright IDEAS* is to permit a variety of possible actions, while retaining the engagement and narrative drive of the original story.

The design of the improvisational agents who answer our casting call must also address several concerns. The agents must provide convincing portrayals of humans facing and discussing difficult personal and social problems. They must have ways of modeling goals, personality and emotion, as well as ways of portraying those models via communicative and evocative gestures. Characters should have a rich back-story that can be presented as needed to give added depth and motivation to the portrayal.

Because of the highly emotional, stressful events being dramatized, and the pedagogical goal of teaching social problem solving skills, the agent architecture was heavily influenced by emotional and personality models coming out of work on human

stress and coping [20] as opposed to the more commonly used models in agent design coming out of a cognitive or linguistic view (e.g., [8,16,17]). Similarly, the gesture models were influenced not only by work on communicative use of gesture [3,15] but also work on non-communicative but emotionally revealing non-verbal behavior coming out of clinical studies [7]. Together, the models provide a rich inner state for the characters to express. To further enhance expressiveness, the agent architecture allows the modeling of concerns, and emotional reactions to those concerns, which are outside the confines of the onscreen action but, nevertheless, impact the action.

A basic question for any interactive drama, but particularly a presentational one, is how to control and direct the action. In our approach, directorial responsibility is shared between the learner and an automated director. The learner directs the thoughts and emotions of the main character in the story, Carmen. Instead of manipulating Carmen as a puppet, the learner controls Carmen at the intentional level, choosing among possible thoughts and feelings that Carmen might have in the current situation. Those thoughts and feelings are incorporated into Carmen's mental model, causing Carmen to act in character in response to them. The automated director controls the actions of the other characters who interact with Carmen. The subtask of handling the cinematography is passed to an off-screen cinematography agent who handles the camera and revelation of story through flashbacks and flash-forwards.

Finally, in terms of presentation, we chose approaches that maximized expressive effect, and tested them to ensure that the intended effect was achieved. For example, to create the voices of the characters we chose to record voice actors instead of using speech synthesis as in Steve [18] and Adele [21]. This ensured that the dialog had sufficient emotional impact. By breaking the voice recordings into individual sentences and assembling them in real time, we were still able to support a significant amount of variability in the generated dialog.

Although the task of creating effective interactive pedagogical drama poses significant challenges, the payoff is sizable. Unlike related work in animated pedagogical agents [10], the agents in these dramas are acting within a story. Building the drama and agents around an effective story should considerably enhance the believability of the characters and their predicaments. In turn, this should enhance both the effectiveness and impact of the interactive experience. Many of the techniques developed here have application beyond education to the broader realm of interactive entertainment.

3. CARMEN'S BRIGHT IDEAS

Carmen's Bright IDEAS relates the problems and stresses of its protagonist, a woman named Carmen, who has a nine-year-old son with pediatric leukemia and a six-year-old daughter. Carmen discusses her problems with a counselor, Gina, who suggests she use Bright IDEAS to help her find solutions. With Gina's help, Carmen goes through the initial steps of Bright IDEAS, then completes the remaining steps on her own.

The story is organized into three acts. In the first act, the learner is presented with a sequence of situation vignettes, each of which dramatizes one of Carmen's problems. They show Carmen interacting with her boss, the doctor in charge of her son's care, her daughter Diana, and other members of her family. These

vignettes provide back-story for the Carmen character, and help encourage the learner to relate to and empathize with Carmen. From the learner's point of view, these situational vignettes are seen as a traditional linear flow of narrative time. The second act takes place mainly in Gina's office. Carmen discusses her problems with Gina, selects a problem to focus on, and develops and evaluates possible solutions. During this discussion the action may flash back as Carmen recalls events that occurred in the past, or flash forward as she imagines possible outcomes of her actions. In the final act Carmen carries out the course of action that she decided upon and observes the consequences.



Figure 1. A distraught Carmen in Gina's office

Figure 1 depicts a shot of the scene in Gina's office. The human mother interacts with the drama by making choices for Carmen such as what problem to work on, what Carmen's inner thoughts are at critical junctures, etc. Figure 2 depicts how interactions are displayed. The mother's selection of inner thoughts for Carmen impacts her emotional state, which in turn impacts her thinking, as well as her behavior. It is Gina's task to keep the social problem solving on track by effectively responding to Carmen's state, and motivating her through dialog and gesture. Meanwhile, a bodiless cinematographer, Alain, is dynamically manipulating the camera views, flashbacks, and flash-forwards.

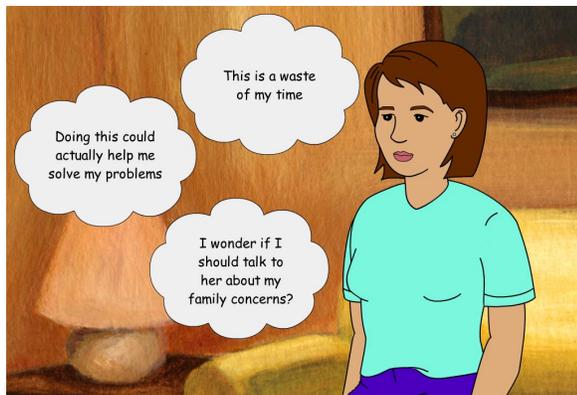


Figure 2. User's choice of thoughts for Carmen

The amount of interactivity and nonlinearity in the story varies greatly from act to act. The first act is presented as a fixed sequence of scenes; however, the mother is still required to respond, by choosing thoughts and emotions for Carmen's reaction to the action in those scenes. This is intended to engage the learner quickly in the story while developing a model of Carmen's mental state that will help guide future actions. The

second act, on the other hand, is much more interactive and nonlinear. It consists of three major scenes corresponding to the "I", "D", and "E" phases of Bright IDEAS, however the set of events in each scene and the timing of transitions from one scene to the next are not fixed. The mother selects Carmen's thoughts, as before, but now Carmen acts immediately upon those thoughts. This in turn prompts responses on the part of Gina, and may cause the cinematographer agent to adjust the camera shot, flashback, or flash-forward. Gina decides when it is appropriate to progress from one scene to the next, and when to continue to the third act of the story. The third act is presented as a linear sequence of scenes, like the first act, but here the choice of scenes depends upon the decisions that Carmen made earlier as to how to solve her problems.

This story design allows the learner to assume different kinds of relationships to story and characters. She may identify with Carmen and have Carmen feel as she would. She may "act out" in ways she would not in front of her counselor. She may flip-flop in choices for Carmen. In any case the story and characters adapt in a fashion that ensures the story and characters retain believability while the pedagogical goals are still achieved.

Although the basic pedagogical model here involves learning by observation, it is not passive observation. The learner plays a constructive role in the drama she observes. And realization via autonomous agents opens the door for additional interactivity even in the current design. The learner could interact at will with Carmen, select a different "personality" for Carmen, or even play a more direct role in the pedagogy by electing to control Gina.

4. SCRIPT DECONSTRUCTION

In our basic design for interactive pedagogical drama, there are five main components: a cast of autonomous character agents, the puppets which are the physical manifestations of those agents, the learner who impacts the behavior of the characters, a director, and a cinematographer. A director agent manages the interactive agent-based drama's onscreen action and its presentation so as to ensure the dramatic and pedagogical goals of the presentation. The director needs to model potential unpredictable turns or variability in the onscreen activity in terms of what is desirable or undesirable, and direct the action accordingly.

We give the director the knowledge it needs by starting with a script that achieves dramatic and pedagogical goals and then systematically deconstructing it in order to determine ways variability can enter the drama. Fundamental to this process is the determination of which variations are desirable, either dramatically or pedagogically, and how to avoid or manage variations that are undesirable.

The script is decomposed into a hierarchical narrative structure, so that variability can be introduced at appropriate levels in the hierarchy. The highest level, the division of the story into acts, is presumed fixed and hence is not a source of variability. At the next level, the script is a sequence of scenes. Variability can be added in several ways here. For example one can consider alternative scenes or different orderings on the scenes, thus turning the linear sequence into a graph [11]. One can consider entirely different scenes that achieve the same goals. Moving down in grain size, alternative realizations of a scene can then be considered. Perhaps different patterns of events can achieve the same scene goals. At a finer grain still, an analysis of the goals of

the characters relative to the events in the scene is useful. Perhaps different characters can cause the same events to occur.

As this hierarchical deconstruction proceeds, it is critical to seek out patterns of similarity in character activities across situations. The patterns suggest general classes of behaviors to include in the agents' behavior repertoire. The differences between similar behaviors help to identify what makes each character distinctive and interesting. This process identifies where desirable variability can enter the script and what are character-appropriate ways of achieving it. Finally, it simplifies the design of the agents by limiting how much detail must be built in.

As a preliminary step to the deconstruction process, a decision has to be made about the nature and attitudes of the director. We might imagine a director that makes it easier for the characters or causes them problems. In addition, we must determine how the director achieves directorial control over characters (e.g., see [2]).

4.1 Deconstruction of *Carmen's Bright IDEAS*

The application of this deconstruction technique to the *Carmen's Bright IDEAS* script lead to several design decisions which we detail here. At the outset, the decision was made to make an onscreen character, Gina, the director. Gina has essentially a pedagogical role with respect to Carmen and by making her director she could assume a similar role toward the learner. And since Gina's role is to help Carmen, this essentially suggested her directorial attitude with respect to the Carmen – she would be very accommodating and helpful. Gina also manages the interactivity, such as the thought balloons shown earlier.

Next a decision had to be made concerning how Gina, as director, would insure that critical goals for the drama are achieved. For example, how does Gina insure that Carmen addresses the "D" step of IDEAS? Of course, she could be provided various kinds of direct control over Carmen that essentially allows her to coerce Carmen's behavior. However, since Gina's role within the drama is to help Carmen work through the problem solving strategy, a far more subtle and challenging approach was taken of only allowing Gina to motivate through onscreen activity. This onscreen activity, of course, must be consistent with the scene itself and the roles of the characters in it. In particular, for act two, all Gina can do is motivate Carmen through the use of dialog. To help Gina, we gave her access to Carmen's emotional state (Carmen has no special access).

This motivation through onscreen activity has an interesting impact on the drama. While Gina is using dialog to motivate Carmen, the learner's interaction is influencing Carmen's thoughts and emotions. That creates a tension in the drama, a tug-of-war between Gina's attempts to motivate Carmen and the initial, possibly less positive, attitudes of the Carmen/learner pair. As the learner plays a role in determining Carmen's attitudes, she assumes a relationship to this tug-of-war, including, ideally, an empathy for Carmen and her difficulties, a responsibility for the onscreen action and perhaps even an empathy for Gina. If Gina gets Carmen to actively engage in applying the Bright IDEAS technique with a positive attitude, then she potentially wins over the learner, giving her a positive attitude. In either case, the learner gets a vivid demonstration of how to apply the technique.

With these design decisions established, we could turn to the deconstruction of the script. In terms of the act level deconstruction, the main variability that was added includes

which problem Carmen chose to work on in act two and which flashbacks and flash-forwards would then follow. Variability was added by allowing the learner to determine Carmen's choice of problem, which also impact the flashbacks and flash-forwards.

In this particular script, the more interesting potential for variability enters at the level of deconstructing the pattern of activity within act two. This act is structured around stepping Carmen through an application of the Bright IDEAS methodology to her problems. The pedagogical goal is to get Carmen through these steps. Alternative paths through the story that do not cover these steps were pedagogically inappropriate.

In the script, Gina has a specific strategy to help Carmen address each step. For example, during Identify, she suggests that Carmen isolate the features of a problem by answering the questions of a 5-Ws strategy:

Gina: OK, Let's take the problem one part at time. We'll start with the old five W's: Who, What, When, Where and Why.

During Develop, Gina suggests a simpler enumeration strategy which does not as explicitly guide Carmen:

Gina: Now we have to develop solutions. That's the "D." Let's brainstorm for solutions. You start. Just throw out an idea. Any idea.

However, these strategies are quite general. For example, one could "Identify the problem," the I, either by enumerating its features or by answering a fixed set of questions about it. Even better, the strategies differ as to how much explicit guidance they provide Carmen, so one can base Gina's choice of strategy on an assessment of Carmen's state. Further, one could imagine many alternative strategies for achieving these steps. So clearly here is a source of variability, the choice of strategy. Gina can choose the appropriate strategy based on which step of IDEAS is being worked and an assessment of how much guidance Carmen needs. And if one strategy doesn't work, she can try another. Note that in the script, as well as in the resulting agent, Gina's pedagogical technique is to *suggest* a strategy to Carmen.

At a finer grain of the deconstruction, we considered how different agents and their interactions could be used to realize these strategies. For example, different characters can take different roles in achieving these solutions. Carmen may begin using a strategy directly or she may need coaxing, or specific prompting of how to address the substeps of the strategy.

Here again, we managed to prescribe a single general model of agent interactions that drove the solution to the strategies being used across the I, D and E steps. The key here is that Gina's consistent goal across steps is to motivate Carmen to address the current step. But there is no way for Gina to force Carmen to apply these strategies. Dialog is Gina's main tool in this struggle and as a well-developed character in the script, there was a consistent "character", or regularity, to her use of dialog.

Figure 3 depicts part of the dialog model for the Gina agent that resulted from the analysis, which is used across the steps of IDEAS. The model consists of a set of dialog acts (similar in spirit to DAMSL [4] but specifically tailored to capturing the character implicit in Gina's dialog). Transitions between dialog acts are governed by whether Carmen has appropriately responded and her emotional state. For example, once Gina proposes a strategy, such as the 5-Ws or Enumeration, there are sequences of subproblems

to be addressed. Answering "who" is the first subproblem in the 5-
Ws strategy. If Carmen does not offer the answer to "who", Gina
may decide to reassure her, dependent on Carmen's emotional
state. Whether or not Gina reassures Carmen, if the answer is still
not forthcoming, then Gina will prompt her. For example, Gina
may say, "Who is involved in the problem?" If that fails, Gina
may prompt more explicitly, or even answer for Carmen. Finally,
depending on whether Carmen managed to address the
subproblem herself, and again what her emotional state is, Gina
may praise her efforts, for example, by saying "Good".

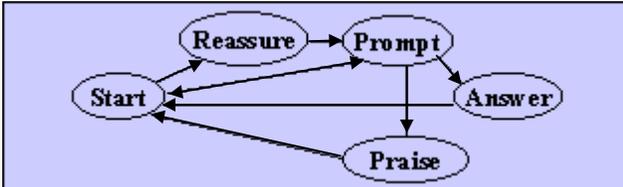


Figure 3. Part of Gina's Dialog Model

Carmen's dialog acts connect her to Gina's use of dialog. Carmen
may answer when asked a question (or be unresponsive), agree (or
not) to a suggestion, complete a strategy without prompts, dismiss
a problem's significance and go off topic in limited ways.

The dialog acts also impact agents emotionally. Carmen may
initially require prompting, but as she is reassured, or the various
subproblems in the strategy are addressed, there will be a positive
impact on Carmen's emotional state. This, in turn, may cause her
to engage the problem solving without the need for explicit
prompting at each step. Similarly, the learner's interaction with
Carmen impacts her emotional state and thus impacts how much
prompting, praise or reassurance is necessary. To accommodate
this variability in the taking of dialog turns, Gina typically sets
and expresses a relatively low willingness to take the next turn. So
if Carmen expresses any willingness to take the next turn in
response to what Gina has just said, she can. However, Gina is the
director, so if she wants the dialog turn, she can preempt Carmen.

Finally, at the lowest level of script analysis are the agent actions.
Again, to achieve character-specific variability and generality, we
analyzed these actions in terms of when they are appropriate and
what effects they have on the drama. In this particular scene, the
major actions are dialog acts realized as recorded speech segments
(phrase, clause or sentence). To achieve variability, these
segments are indexed by several applicability conditions,
including the dialog act or acts it addresses (e.g., Prompt), and
whether it is specific to a strategy, a step in a strategy (e.g., the
What step), a particular problem (i.e., a topic such as Diana's
tantrums) or a point in the dialog. Dialog segments can also be
indexed by emotional state of the speaker and listener. Currently,
the agent chooses from the set of applicable dialog segments
based on specificity of the applicability conditions and recency of
use, the effect being that very specific dialog segments tend to be
used if applicable and segments that are least recently used are
preferred. For every dialog act, there is a default move that is
always applicable. For example, for praise, it is to say "Good".

The dialog segments are also annotated to model their effects, or
impact, on the agents. This includes a characterization of the
segment's topic in terms of the dialog act models. For example,
does the segment truly answer a question such as why Carmen's
daughter Diana is having tantrums or does it simply dismiss the
tantrums? The annotations also include timing information for the

speaker's and listener's non-verbal behavior (emphasis points,
points where abstract use of deictic reference is possible, when the
main point is expressed, etc.) Note these represent potentials, the
actual non-verbal behaviors are determined dynamically by an
agent's reaction to the annotations.

5. AGENT ARCHITECTURE DETAILS

Here we touch upon a few aspects of the agent architecture as they
pertain to interactive pedagogical dramas. The underlying
architecture for all the agents is based on Situation Spaces [14], a
multi-layer transition-based agent model. For onscreen characters,
there are distinct layers for problem solving, dialog model,
physical focus and emotional appraisal.

In the case of Gina, the problem solving layer models the dramatic
structure, including the IDEAS steps and what strategy Gina is
using to realize the current step. We saw earlier a portion of her
dialog model, which drives the execution of strategies. Carmen
has more reactive and simpler problem solving and dialog layers,
which allow her to respond to Gina's dialog. Physical focus
manages the agent's non-verbal behavior and emotional appraisal
comprises the agent's emotional model.

In Carmen's Bright Ideas, the world-events processed by the
agents are the dialog annotations. For the agents, the annotations,
along with the problem-solving context, reveal the meaning of
what is being said and timing of events. The agents experience the
annotations in order, so it is possible for their internal state and
appearance to be in flux over the dialog segment. As events are
processed, various non-verbal behaviors are generated which are
passed on to the puppets via the cinematographer.

A simple example illustrates how the layers process dialog.
During Identify, Gina may ask why Diana is having temper
tantrums. Carmen, because she is feeling anxious about being
judged a bad mother (emotional appraisal), copes (problem
solving layer) by *dismissing* the significance of the tantrums. She
answers (dialog model): "She is just being babyish, she wants
attention." The annotations for this dialog and Carmen's
emotional state bias physical focus to generate relevant behaviors
(e.g., fidgeting with her hands). The annotations also lead to
emotional re-appraisal. She may now feel guilty for "de-
humanizing" her child (emotional appraisal) and may physically
display that feeling (physical focus). Meanwhile, Gina, who is
also processing the annotations, will not accept this dismissal as
an answer for it fails to address the cause of the tantrums in a
constructive fashion.

Non-verbal behaviors are generated by the physical focus layer,
which characterizes the mix of non-verbal behavior exhibited by
an agent. At any point in time, the agent will be in one of four
modes based on emotional state that predisposes it to use
particular non-verbal behavior in a particular fashion. Each
behavior available to an agent is categorized according to which
subset of these modes it is consistent with. Any specific non-
verbal behavior, such as a particular nod of the head, may exist in
more than one mode and conversely a type of behavior, such as
head nods in general, may be realized differently in different
modes. Transitions between modes are based on emotional state.

In the current model, we have delineated four modes: strong
body-focus, body-focus, transitional and communicative (based
on work by [7]). Strong-body focus is marked by a self-focused
attention, away from the conversation and the problem-solving

behavior. Emotionally, it is associated with considerable depression or guilt. Physically, it is associated with the tendencies of gaze aversion, paused or inhibited verbal activity and hand to body stimulation that is either soothing (e.g., rhythmic stroking of forearm) or self-punitive (e.g., squeezing or scratching of forearm). Body focus indicates a more moderate withdrawal that in the agent tends to be indicated physically by hand to hand fidgeting. Continuing this trend, transitional indicates an even less divided attention, less anxiety, a burgeoning willingness to take part in the conversation, milder conflicts with the problem solving and a closer relation to the listener. Physically, it can be marked by hand to object gestures, such as playing with a pen. Finally, communicative indicates a full willingness, or intent, to engage in the dialog and problem solving. Physically, it is marked by the agent's full range of communicative gestures (e.g., beat or deictic [15]) and use of gaze in turn taking.

Now let's consider emotional appraisal. It is a key part of the design. For example, it biases the agent's use of gesture and gaze as just discussed, determines how it engages in problem solving, impacts dialog and provides a means for motivating Carmen.

There is a large body of research in emotion models. In much of this work, emotions can be roughly characterized as comprising an appraisal of events in the world with respect to one's goals or attitudes, perhaps some physiological response and some form of disposition or action tendency. Models differ considerably as to what constitutes a basic emotion, how the appraisal process is structured, how tightly emotion is coupled to an agent's plans and whether the physiological response is considered to be a constituent part of the emotion.

All of these factors are deeply significant for agent character design. However, pragmatically, we posited several requirements for emotional models in pedagogical dramas. The emotional model had to provide a believable rendering of the relation of emotion to the coping strategies essential in problem solving skill development. The modeling also required certain dynamics. For example, thoughts and memories related to a character's problems should impact current emotional appraisal across problems. Carmen's depression over her son might affect her hope about resolving her daughter's problem. Similarly, the success or failure of an agent's problem solving must also impact emotional state.

Because of their emphasis on stress and coping, we based our model on work by Smith & Lazarus [20]. Their work posits a two-step appraisal process. Primary appraisal establishes whether the event is relevant to an agent's motivations and whether it is congruent or incongruent to those motivations. Secondary appraisal evaluates 4 factors: accountability, expectancy, problem-directed coping potential and emotion-directed coping potential. Accountability establishes who, if anyone, is to blame for a motivationally incongruent event. If the agent is to blame, there may be self-directed anger, or guilt if another also suffers. Expectancy establishes whether there is hope that matters will get better. Coping potentials are an assessment of how effectively the agent will be able to cope. Could the agent effectively change the world to make it more congruent (problem-directed coping) or adjust psychologically (emotion-directed coping)? These appraisals in turn establish the emotional state. Though parsimonious, this model effectively captured the factors we sought to model in pedagogical dramas.

Currently, a simple dynamics controls this model, which in turn helps to control the emotional state and behavior of the agents. Motivational congruency is a binary value while motivational relevance, expectancy and the coping potentials are scales. Each agent has emotional appraisal rules, which set these values by analyzing the spoken or heard dialog annotations and problem solving activity. For example, successful problem solving, such as Carmen developing a plan for Diana's tantrums, increases confidence in problem directed coping and expectancy for that problem. These changes in turn impact Carmen's willingness to engage in the problem solving, shifts her between physical focus modes, etc. Similarly, Gina's reassurances impact Carmen. Every problem situation Carmen faces also has a memory of appraisal values. When that problem becomes the current focus, its appraisal values are re-established either directly or, in the case of coping and expectancy, by averaging in the current state of the appraisal using a weighted sum based on motivational relevance.

Gina's use of thought balloons to interact with the learner also is based on this model. Gina generates thought balloon requests at critical junctures in the drama, such as when the problem-solving step changes. The learner is presented with 3 alternative thoughts selected from a larger pool – representing no change in Carmen's emotional state, a negative change and a positive change. When the learner selects one, Carmen's emotional state is modified.

Emotional appraisal and physical focus are designed to be general across agents. However realism also requires that they incorporate knowledge about individual differences, as in human behavior. For example, Carmen's ego-identity as a mother is a key part of her emotional appraisal rules. Similarly, Carmen's repertoire of gestures incorporates individual differences. The creation of such differences again benefited from the script deconstruction.

6. CINEMATOGRAPHY

To set up the filming of the onscreen action, there is an offscreen agent we call Alain. It's Alain's task to manage the shooting of the drama dynamically to assure dramatic impact. Alain gets a filming description from the onscreen agents of a single dialog turn. This is a description of the action that needs to take place in the next dialog turn, including who is speaking, what is said, the non-verbal behavior, the temporal synchronization of the behaviors and what if any thought balloons or flashbacks will occur. Additionally, the filming description includes the emotional state of the agent and which agent is taking the next turn in the dialog.

Alain then uses a set of rules to decide whether shot changes need to be added to this description. For example, if an agent's spoken line is very long then the shot (camera's location) is changed if necessary to show that agent. If possible, the shot will be changed to favor any strong emotive behavior or a key pedagogical point by Gina. Thought balloons require a point-of-view with a focus on the thinking character.

Alain also translates the filming description into a form that includes the verbal behavior plus all the specific body part and timing details needed to animate the puppets non-verbal behavior. As an example of the latter, Carmen might request her puppet to sequentially prop her elbow on the sofa arm, and then lean her head onto her hand by simultaneously moving the arm, body and head, pauses 15 ticks, then lower her eyes. Alain turns this into the description below. The seq and par markers establish whether the embedded animation requests are performed in sequence or in

parallel. Each animation request specifies the puppet (e.g., Carmen), the body part (e.g., brows) and what action to take, specified as frame numbers to sequence through. Alain passes such descriptions on to the puppet architecture which figures out how to piece the animation requests together for the current camera location, as well as dynamically derive the lip syncing for any speaking part.

```
(seq <ani,Carmen,backarm,32,48,0>
  (par <ani,Carmen,backarm,67,84,0>
    <ani,Carmen,body,67,84,0>
    <ani,Carmen,head,67,84,0>
    <ani,Carmen,brows,240,240,0>)
  <Pause,15>
  <ani,Carmen,eyes,100,100,0>)
```

7. ANIMATED PUPPET ARCHITECTURE

The presentation style for Carmen's Bright IDEAS was a critical concern. It needed to be flexible in order to support agent-controlled characters, and suitable for the target audience. Due to the nature of the drama, high quality speech was considered necessary. An animated approach was chosen that used recorded voice. Animation is not usually the first thing one thinks of in creating stories for adults. Adults in our target age group, however, grew up with Saturday morning cartoons, Disney, and even Fritz the Cat.

The animation style we chose was the limited-animation style of Saturday morning television. As 2D animation styles go, it is produced relatively quickly. 3D styles were also considered and rejected, because richly expressive 3D characters still require accelerated graphics and tend to have a robot-like or artificial appearance. Our characters required believability, not realism.

The 2D style also permits the use of vector graphics. Vector graphics files are small compared with bitmap graphics files, a key concern since the puppets are composed of hundreds of layers and frames of artwork. Vector animation is resolution independent and scalable, thus allowing us to provide Alain with a reasonable variety of focal lengths to frame and feature his actors. Bitmap graphics were used for the backgrounds, however. This provides a visual contrast for our characters, one that is reminiscent of traditional television animation, and allows for greater latitude in visual expression. The disadvantages of 2D over 3D are clear, however, in a procedural context. A large repertoire of behaviors for our 2D puppets is not possible at this stage due to the amount of artwork required. The puppets for the interactive prototype have an acceptable range of possible behaviors only because the narrative domain, dyadic conversation, is limited.

The puppet structure is built of layered, non-linear, flip-book images on transparent backgrounds. The agent who pulls the puppet strings (i.e., sends messages) keeps track of which combinations of frames or sequences will best dramatize its characters. Putting it in Behavior Space terms [12], the agent uses the puppet to manifest behavior fragments. The agent coordinates the behavior fragments with the necessary visual segments (body parts) which are, in effect, libraries of gestures and expressions. This differs from traditional behavior-space approach in that it does not maintain a fixed viewpoint, but at the present time, it is a non-generative approach.

8. STATUS & RESULTS

We tested a conceptual prototype with a small group (4) of mothers of pediatric cancer patients. Key issues we wanted to investigate were viewer identification and situation believability. Both the characters and their appearance were validated by the testers as being sympathetic and believable, as were the scenarios themselves. The testers believed Carmen to be "average" in her ability to cope with her problems and found her solutions believable. The testers also found Gina's presentation of the Bright IDEAS concepts to be clear, easy to follow and helpful in reinforcing their understanding of the method.

We were interested in knowing if the mothers felt the story was an appropriate length, if it held their attention, and if they would be likely to view the program on their own while in the clinic. They were asked whether they would prefer to view Carmen's story via the computer animation, or to read her story in a book. Positive responses were received to all these questions. One mother commented that, although she was an avid reader, she found the hospital environment too distracting to read a story, but would find the computer animation a welcome relief from the anxiety of waiting for her child's treatment to conclude. In short, the results of our focus test indicated that in all respects tested, we were on the right track with both structure and presentation.

The present prototype is being assembled for testing in a clinical setting. This program will include several example situation vignettes, and their corresponding possible outcome vignettes. Professional artists and animators are creating the animation and backgrounds. Actors were employed to portray the characters in the voice recordings, and the sound has been mixed and coded for lip-syncing. An ambient soundtrack is being created to bring the background settings to life. The sample situation vignettes by no means constitute the full library we hope eventually to build, but it should provide enough variability to test the program design in the clinical trials.

The interactive prototype will join the other learning materials (brochures, worksheets, etc.) prepared for the Bright IDEAS clinical intervention. The next round of clinical trials, beginning mid 2000, will incorporate the computerized program into the current training program for one set of learners, where it will substitute for three meetings between the learner and the counselor teaching Bright IDEAS. The remaining group of learners will receive the traditional set of five personal interventions with the counselor.

9. CONCLUSION & FUTURE WORK

In this paper, we have described an approach to developing interactive pedagogical drama that draws on both creative influences and science. It takes as a starting point an engaging linear script and deconstructs it in order to guide the design of autonomous agents that realize the interactive drama. To add to the realism, the deconstruction and resulting agent models rely on research into human emotions, non-verbal behavior and dialog. The agents control the behaviors of lifelike interactive characters and frame the presentation of the action; directorial responsibility is shared between the user and an automated director.

Once the current round of clinical trials with the *Carmen's Bright IDEAS* prototype are completed, we plan to extend the title to include a wider range of problem scenarios and outcomes. We also plan to incorporate a greater degree of tailorability, so that

scenes can be adapted according to learner characteristics. It would be desirable to give the learner more options in defining the problems that Carmen faces, and in deciding how Carmen chooses to solve them. It would also be useful to have a variety of characters with different personalities and backgrounds that can be inserted into the story, in order to increase the story's appeal to different individuals.

Finally, since the story deconstruction approach and the agent-based story delivery engine appear to be quite general, we wish to apply the approach to other pedagogical stories. The approach should be applicable to other health interventions, as well as educational applications that involve problem solving in social situations.

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