A Pedagogical Agent for Psychosocial Intervention on a Handheld Computer

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Abstract

Embodied conversational agents (ECA) have potential as facilitators for health interventions. However, their utility is limited as long as people must sit down in front of a computer to access them. This paper describes a project that is deploying an ECA on a handheld computer, and using it to assist in a psychosocial intervention aimed at providing training in problem solving skills. The agent is based upon the virtual trainer/counselor in the pedagogical drama *Carmen's Bright IDEAS*, adapted for handheld use and for interaction with a human caregiver. The system will go into clinical trails in August of 2004. The paper discusses the design and technical issues involved in the transition from laptop computer to handheld device and from 3rd-person view to first-person interaction, and the plan for evaluation. The clinical trial is designed both to evaluate psychosocial outcomes and to assess user preferences in ECA interaction modalities over the course of multiple sessions of use.

Introduction

Embodied conversational agents (ECA) (Cassell et al., 2000) show potential as facilitators for health interventions. ECAs exploit people's general tendency to relate with computer media at a social level (Reeves and Nass, 1996). Agents can depict people who are dealing with health-related problems, and guides and counselors who help people to overcome these problems. In the role of counselors, agents offer the potential of employing their social skills to enter into working alliances with patients or caregivers in order to facilitate the health intervention. Examples of ECA-based health interventions include *Carmen's Bright IDEAS* (Marsella et al., 2003), FitTrack (Bickmore. 2003), and the VICTEC project (Woods et al., 2003).

Although some of these systems (e.g., *Carmen's Bright IDEAS*) are showing some positive health outcomes, they suffer from an obvious limitation: the user must sit in front of a computer in order to interact with them. This disassociates the agent from the situations where health intervention is most likely to be needed. For example, *Carmen's Bright IDEAS* is designed to help caregivers to cope with the problems they encounter related to care giving, but caregivers only have access to it once a week at the pediatric care clinic, where they are not engaged in care giving. The Laura agent in FitTrack is designed to help people improve their exercise habits, but it is difficult to communicate with Laura while exercising.

This paper describes an effort to integrate an embodied pedagogical agent into a psychosocial intervention deployed on a handheld computer. Subjects can carry the handheld computer with them during their daily activities. This enables the agent to interact more frequently with users at times that are appropriate for the psychosocial intervention. The relatively low cost of handheld devices make it easy to deliver the intervention to a broad population. In the course of clinical trials beginning in August of 2004, we plan to evaluate the effectiveness of the psychosocial intervention, and assess how the agent contributes to its effectiveness.

We also wish to investigate user preferences in interacting with conversational agents in this context. The test population is very heterogeneous in terms of problem solving orientation, computer literacy, and even written literacy. Users will interact with the agent on at least a daily basis over a period of eight to ten weeks. We expect to find substantial differences in user attitudes toward animated agents, and we expect those attitudes to change as users become more familiar with the handheld application and the problem solving method that it trains.

The handheld computer platform places limitations on the functionality of an embodied conversational agent. For example, it is difficult to render high-quality animation and at the same time engage in a complex natural language dialog. We nevertheless hypothesize that even an ECA with limited capabilities will facilitate user acceptance and contribute to the overall effectiveness of the health intervention. Moreover, handheld computer displays offer some technical advantages for ECA design; the small screen makes imperfections in animation less readily apparent, and in general may lower user expectations

regarding production values. In this case we took an existing agent for a desktop application, namely the Gina character in *Carmen's Bright IDEAS*, and adapted her for deployment on a handheld device. The project thus serves as a case study in the design tradeoffs for similar conversational agents on different platforms.

DESIA Overview

Gina is part of a handheld system called DESIA, a psychosocial intervention designed to help teach caregivers problem solving skills. DESIA helps mothers of pediatric cancer patients to apply the Bright IDEAS problem solving method (Varni et al., 1999; Sahler et al., 2002; Sahler et al., 2004). IDEAS is an acronym for Identify the problem, Develop options, Evaluate the options, Act, and See if it worked. It is a systematic method for addressing problems. Preliminary analysis of the results of a clinical trial indicate that training in the Bright IDEAS method leads to significant improvements in problem solving abilities and reduction in negative affectivity (Dolgin, Phipps, et al., 2000).

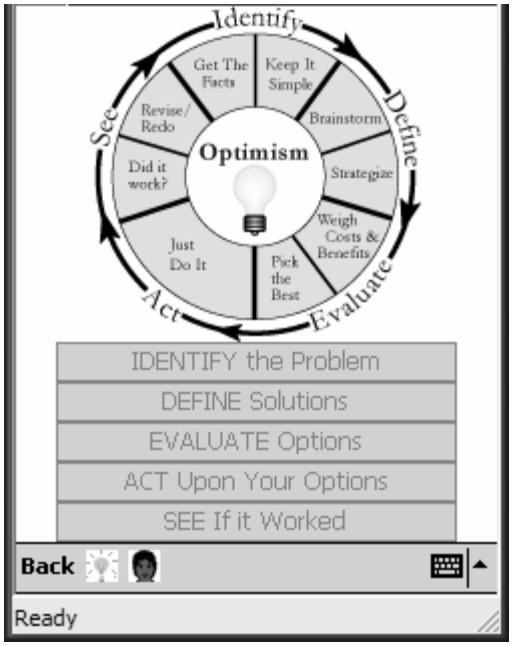

Figure 1. A DESIA screen

DESIA (an anagram of IDEAS) runs on a Pocket PC that mothers can carry around with them. DESIA lets mothers keep track of problems that they are working on, and steps them through the Bright IDEAS process with each problem. Figure 1 shows one of the DESIA screens, displaying the stages of the Bright IDEAS method. Mothers are asked to use it on a regular basis, as needed or as prompted by reminder alarms. It also performs ecological momentary assessment (EMA), asking mothers to describe their emotional state when they work on a problem. When mothers visit the pediatric cancer clinic, the data on the Pocket PC is uploaded to a computer at the clinic, and a trained counselor reviews the data with the mother and gives suggestions for how to improve their problem solving skills. DESIA is being developed by BusinessGoals, LLC. and the Gina component is being developed by the University of Southern California's Center for Advanced Research in Technology for Education (CARTE), as part of a multi-site research consortium headed by O.J. Sahler of the University of Rochester Medical Center.

Figure 2. Gina

A conversational agent, Gina, is incorporated into the DESIA application (see Figure 2). Gina is intended to help mothers learn to use the DESIA application and apply the Bright IDEAS method. Gina is adapted from the counselor character of the same name in *Carmen's Bright IDEAS*. However, instead of interacting with a fictional character, Carmen, this Gina interacts with the user, and serves as a pedagogical agent (Johnson et al., 2000). Nevertheless the function of the agent in this application was sufficiently similar to the counselor character that we concluded that it would be appropriate to create a character with a similar personality, and adapt the artwork developed for the *Carmen's Bright IDEAS* application. In particular, this Gina character should be professional yet empathetic, seek to develop a working alliance with the user, and encourage the user to devote effort to describing problems and developing solutions for them.

Gina's Presentation and Interaction

DESIA needs to support a wide range of users and user preferences. The mothers who participate in the Bright IDEAS program are recruited from the general population of mothers of pediatric cancer patents at the participating cancer centers in the United States and Israel. Many are relatively unfamiliar with computer technology. Many are immigrants with limited literacy skills and limited command of English. Moreover, we expect user preferences for using DESIA and Gina will change over time and depend upon when and where the application is being used. Mothers may initially want a significant amount of coaching and feedback from Gina, and later rely less on Gina's feedback. Users with limited literacy skills might find Gina's speaking voice to aid in comprehension, but still want to turn it off when they are using DESIA in public places.

To meet these constraints, a set of configuration parameters are provided to customize Gina's interaction with the user. Gina is designed to support interaction in multiple languages; as soon as the current English version is complete a Spanish version will be developed in late 2004.

Users may select either a high or a low degree of helpfulness from Gina. In high helpfulness mode, Gina explains DESIA and Bright IDEAS in detail, and walks the user through the problem solving process. In low helpfulness mode Gina provides short prompts and acknowledgments. Some additional dialog may be selected automatically by Gina depending upon how frequently the user has worked with a particular page. Gina can give different comments in each of three different cases: 1) when the user visits a screen for the first time ever, 2) when the user visits a screen for the first time in the current session, and 3) upon subsequent visits to the screen.

Users can also choose which modalities are employed for presenting Gina. In default presentation mode, Gina appears as an animated figure with a speaking voice, as shown in Figure 2, and Gina's voice also appears as a caption. Users may choose to turn off the speaking voice and just leave the caption. They can also turn off Gina's animation. They can turn Gina on and off at any time, by clicking a button on the bottom of the screen. When mothers first use Gina the research associate assigned to them by the cancer center will enable both voice and animation. The mother or the research associate can then change the configuration later in accordance with the mother's preferences.

Gina's interaction depends in part upon the number of times the mother interacts with the program. DESIA keeps a log of the history of the user's interaction with the program, including the number of times she has visited each individual screen. When the mother visits a screen for the first time Gina gives more extensive information about the screen and how to operate it, and explains the corresponding step in the Bright IDEAS method. The explanations are more limited during subsequent uses, and the explanations of the Bright IDEAS method in particular are omitted. In clinical use the research associate first walks the user through the use of the program, and then resets the interaction history before the mother takes the device home. Thus when the mother first uses DESIA at home Gina walks the mother through DESIA and Bright IDEAS again, to reinforce the training provided by the research associate at the clinic.

Gina's dialog is designed to motivate the user, display empathy, and develop rapport, all aspects of developing a working alliance between the agent and the user. Dialog texts have been developed collaboratively by the Gina developers, the directors of pediatric psycho-oncology programs, and the clinical psychologists participating in the DESIA project, particularly Dr. O.J. Sahler. The Gina voice is also used on some screens to speak user screen selections, in order to help mothers with low literacy to comprehend screen text.

Choice of dialog utterances was further influenced by the politeness theory of Brown & Levinson (1987), the work of Lepper et al. (1993) on motivational tutoring tactics, and their realization in the socially intelligent tutorial dialog work of Johnson et al. (2004a, 2004b). Politeness theory was used to analyze candidate Gina utterances, analyze how the scripts exhibited politeness, and to identify areas where Gina's dialog needed to be improved to express more politeness and empathy. The final version of Gina's dialog exhibits the following characteristics:

- Encouragement, e.g., to address hard problems ("Don't let negative thoughts stop you!"), in response to the mother's progress ("Keep up the good work!"), or in response to negative affect expressed by the mother ("I hope you can become more optimistic about solving this problem. Hang in there!")
- Empathy with the mother's situation in general, and in response to poor problem solving outcomes, e.g., "Clearly this was not as satisfactory as you had hoped it might be."
- Respect for autonomy (negative face), e.g., "You may find it helpful to describe the problem using the 5 Ws.
- Redressive strategies such as politeness and deflecting blame to counteract face threats in the interaction, e.g., "I didn't recognize that PIN. Could you please try it again?" or "Please rank your solutions, beginning with 1 for the best solution."
- Promotion of positive face through shared problem solving goals, e.g., "Let's get started," or "Let's move on to defining solutions."

These utterances are coupled with animations and gestures that connote encouragement, empathy, etc.

Choice of wording, choice of gesture, and tone of voice can all play a role in making Gina give an impression of sensitivity and social intelligence, and promoting user motivation. We therefore used recorded lines, spoken by a voice actress, for Gina's voice. Although there has been recent progress in developing expressive qualities in synthetic voices (Johnson et al., 2002), high-quality speech synthesis is not yet available on handheld devices. Recorded well-acted speech remains the best option, even if it restricts the flexibility of agent dialog. In practice, the empathetic aspects of vocal production proved critical, and lines were re-recorded as necessary until the vocal delivery expressed proper affect and empathy.

The expressiveness of Gina's presentations in DESIA is of course constrained by the user preferences. Expressive tone of voice will have no impression on the user if the user has turned off voice output. We decided that in this application user configurability was of paramount importance, even if it dilutes the ability of the agent to convey social intelligence. However since social intelligence can be conveyed via multiple modalities Gina can express aspects of social sensitivity to all users, regardless of display configuration.

Gina can communicate to the user at several points as she visits a particular DESIA screen. When DESIA displays each screen, it calls Gina to notify her that a new screen is visible. Gina has the option at that point of giving guidance or explanation about that page or the step in Bright IDEAS that that page helps address. DESIA also passes to Gina the name of the problem that the user is currently working on, so that Gina can refer to that particular problem as appropriate. DESIA also notifies Gina when the user makes selected entries on the display, to give Gina the opportunity to speak those entries, acknowledge the learner's action, and/or encourage her to continue. If the user requests help with a particular screen, Gina will explain that screen in more detail. Finally, DESIA can notify Gina when the learner has completed a particular screen, so that Gina can comment on the user's progress and offer further encouragement.

Gina's ability to express empathy depends upon her ability to judge the attitudes and emotional state of the user. This information can come from three sources: a short ecological momentary assessment (EMA) questionnaire administered during interaction, the mother's progress and success in solving problems, and her attitude toward solving problems, in particular her level of optimism. The current version of Gina responds immediately to expressed optimism and problem solving progress. There is no direct reaction to the EMA questions in the current version, as we first wish to collect data in the clinical trial to understand how assessed mood correlates with problem solving progress and optimism. Such responses can be easily added in later in the trial.

Gina interaction with the user is constrained by the characteristics of the Pocket PC display. If the user chooses to display Gina's persona, it not feasible to display the full persona at all times. Screen real estate is a scarce resource, and display area allocated to Gina is not available for other DESIA interface objects such as captions, buttons, and data entry fields. The display design should give the impression that Gina is present, and hence engaged in a working alliance with the user, but not interfere with the user's operation of the interface.

To minimize contention for screen real estate, Gina's persona is displayed in one of three forms: as a full-screen close-up shot, as a small thumbnail image of Gina's face in the top left corner of the screen, and as a disembodied voice. The choice of image depends upon the particular screen and user interaction. Full-screen display is used at the beginning and end of the session. In the screens that appear toward the beginning of a session, when the user is first being introduced to the application, we make greater use of the full-screen display. If Gina is explaining how to operate a particular screen, Gina appears in thumbnail form so that she can comment on the display without obscuring the display. Voiceover mode is used when the screen is fully occupied with written material, or when the animation might distract the user's visual attention from the written material. In practice the use of an empathetic voice is critical to convey Gina's continued presence and engagement in the user's activities.

Figure 3. Gina gesturing

The small display size of the Pocket PC, and the thumbnail view of Gina in particular, have implications for the art design of the agent. Although our desire was to reuse what we could of the Gina artwork created for *Carmen's Bright IDEAS*, it was not clear how much we would be able to do

this, since Carmen is designed for a larger display. As it turned out, the basic character design could be transferred without substantial modification. Gina was rendered in cartoon animation, where the facial features were outlined and clearly visible; this made the gestures relatively easy to read on a small display. However, some gestures had to be revised because less of Gina's body is visible, so hand gesture space is closer to Gina's face (Figure 3).

Animation on the handheld device was in some respects simpler because lip synchronization was less of a concern. In *Carmen's Bright IDEAS* characters were frequently presented in close-up views, were lip synchronization problems were clearly visible. On the Pocket PC lip shape is less easily visible, and simple lip-flapping without phoneme synchronization appears to be adequate, provided that the Pocket PC is running at maximum processor speed.

Implementation

Gina is implemented in Macromedia Flash using ActionScript and the .NET Compact Framework using C#. Gina's agent control mechanism is exposed to the DESIA application as a standard .NET component. Internally, Gina communicates with the embedded Flash ActiveX control with the help of the CFCOM library. The integrated system runs on a Dell Axim X3 Pocket PC.

The Gina persona composes and plays a combination of animation and sound resources loaded onto the Pocket PC. Spoken lines are stored as MP3 files. As in *Carmen's Bright IDEAS*, animation is stored as a collection of animations for each body part, superimposed as layers. A collection of sequences of animation frames are created for each body part; these are composed in real time as needed.

The Gina animation control system is based upon the Digital Puppets system developed for Web-based agents (Shaw et al., 2004). Agent behavior is a combination of scripted behaviors and background behaviors generated automatically. This approach simplifies behavior authoring since it is not necessary to script behaviors in detail. It also reduces the repetitiveness of the behavior, an issue that is important for a character that is designed to interact with users over an extended series of sessions.

Character behavior is specified in an XML syntax and loaded when the agent starts. Behavior is specified for *scenes*, where each scene represents a DESIA screen in some context state. As new functions are added to DESIA or new responses added to Gina incremental changes can be made to the scene specifications to support them.

Behavior authoring in Gina proceeds as follows. First, a repertoire of gestures is created on a frame-by-frame basis. Some gestures are marked as background behaviors. For a given scene, sound clips for Gina's lines are selected. For each clip, key time points for gestures are identified. Gestures are assigned to those time points. Finally additional individual frames may be inserted to smooth out the animation sequencing. Once the basic gestures were defined, authoring Gina behaviors is relatively straightforward. Animators are able to refine the animations iteratively by updating the XML file. They can then test the animations either using a test application that runs on a desktop computer, or by downloading them to the handheld computer and testing them in DESIA.

```
<scene name="Splash">
 <condition visit="0,1,2" help="0">
  <cmd frame="0"
       value="SAY Gina-K005.mp3" />
  <cmd frame="35"
       value="SAY Gina-K006.mp3" />
  <cmd frame="65" value="EOS" />
 </condition>
 <condition visit="0,1,2" help="1">
  <cmd frame="0"
       value="SAY Gina-K001.mp3" />
  <cmd frame="1"
       value="HOLD 11,19,steeple"
       dur="3" />
  <cmd frame="3"
       value="POSE tiltDownRt_smile" />
  <cmd frame="7"
       value="HOLD 5,13,*" dur="2" />
  <cmd frame="10"
       value="HOLD 22,31,*" dur="3" />
  <cmd frame="15"
       value="POSE blink_smile" />
  <cmd frame="35"
       value="SAY Gina-K005.mp3" />
  <cmd frame="70"
       value="SAY Gina-K006.mp3" />
  <cmd frame="100" value="EOS" />
 </condition>
</scene>
```

Figure 4. Sample specification of Gina behavior

Figure 4 shows part of the scene description for the "Splash" screen, the screen shown in Figure 2. Here Gina pops up and introduces the DESIA application to the user. The specification defines two conditions under which the Gina should perform a behavior, and the behavior under those conditions. `visit` represents the number of times that the scene has been visited before (0 = never, 1 = once, and 2 = multiple times). `help` represents the level of helpfulness assigned to Gina (0 = low, 1 = high). Following this is a series of commands, each of which specifies the time when an action should occur (measured in frames), and a primitive action for the agent to perform.

The following primitive commands are supported by Gina:

- SAY <mp3 file>: play an MP3 sound file.
- POSE <gesture name>: play an animation sequence

- HOLD <face frame>, <eyes frame>, <body frame>: switch Gina to play a particular face-eyes-body combination. This is used to tweak animations particularly between animation sequences.
- EOS: end of scene. This causes Gina to be removed from the screen.

Evaluation

Evaluations will assess user problem solving ability and negative affectivity over time, and assess to what extent DESIA and Gina contribute to these changes. Assessments will also examine user attitudes toward Gina, and the manner in which users made use of Gina, e.g., what presentation style the user chose at what times.

Training for the research associates in using DESIA took place in July 2004, and subject accrual at four participating cancer centers started in August 2004. Subject accrual will continue for a period of three years. Subjects will be drawn from a pool of all mothers who are primary caregivers of children diagnosed with any form of cancer 2-16 weeks prior to contact. If they consent to participate, they will be randomized into one of three experimental groups: a DESIA treatment group, a treatment group receiving paper-based Bright IDEAS training, and group receiving time-and-attention therapy but no problem solving skills training. Approximately two hundred fifty subjects will be recruited for each arm. Subjects in the DESIA arm initially will receive the English-language version of DESIA; when the Spanish version is ready then mothers will receive either the English version or the Spanish version depending upon their preferred language.

Subject problem solving skills will be assessed using the Social Problem Solving Skills Inventory – Revised (SPSI-R). Spanish-speaking subjects will also complete the Immigrant Stress subscale of the Hispanic Stress Inventory. To test their problem solving skills, the mothers will be presented with fictionalized vignettes involving mothers facing problems, and will be asked to solve them. The mothers' solutions will be scored as to what extent they apply the principles of the Bright IDEAS method. Additionally, instruments will be employed to assess subjects' negative affectivity and mood state.

Each treatment will consist of eight one-hour sessions, during which subjects will meet periodically with their assigned counselors and subjects in the DESIA arm will have continuous access to a Pocket PC with DESIA. Upon completion of the treatment, and again 12 weeks after that, participant problem solving skills and negative affectivity will be assessed.

Finally, the evaluation will assess the participants' use of DESIA and Gina and their role in promoting effective problem solving skills. Data from the users' interaction with DESIA will be uploaded to a database and recorded, as will the users' chosen configuration parameters for Gina. This will enable us to measure the frequency of use of DESIA, the number of problems that the users solve, the types of responses that the users receive from Gina, and the users' preferences for configuring Gina. In addition, participants will complete a Likert-scale questionnaire regarding DESIA and Gina. The questionnaire statements relating to Gina assess the following:

- Attitudes toward using Gina, e.g., "I liked working with Gina",
- Impressions of Gina's helpfulness, e.g., "Gina helped me to learn DESIA," "Gina helped me learn to apply the Bright IDEAS method",
- Attitudes toward Gina as virtual counselor, e.g., "Gina understood my problems", "Gina helped me to feel better about my problems", and
- Reasons for interacting with Gina, e.g., "I found it helpful to work with Gina even after I had learned to use DESIA."

Questions relating to DESIA assess the following:

- Ease of use, e.g., "The DESIA handheld computer and its applications were easy to use",
- Convenience, e.g., "I found it easy to keep the handheld computer with me to record my problems and solutions", and
- Particular features, e.g., "The ability to do a voice recording was helpful."

This experimental design should make it possible to determine whether the Gina animated agent is helpful, and assess how the subjects use Gina. It will not however provide a direct comparison of subjects using Gina and subjects not using Gina. Adding such an experimental comparison would increase the number of experimental arms and reduce the statistical power of the results in each arm, and therefore would interfere with the other research goals of the study.

Conclusions

Gina is an animated pedagogical agent designed to support a health intervention deployed on a handheld computer. Deploying the application on a handheld device makes it possible for users to interact with the health intervention on a frequent basis, increasing the likelihood that it will have a positive impact on health-related behavior. Although the handheld device platform is limited in terms of processing power and display size, it makes the agent available to the user on a continuous basis, offering the possibility for the agent to develop a stronger working alliance with the user. This application offers an excellent opportunity to assess user interactions with and preferences toward animated agents, and observe how they change over time. Planned evaluations will also assess user attitudes toward Gina, and

examine whether this has an effect on the effectiveness of the health intervention.

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