A Smartphone-based Virtual Agent for Atrial Fibrillation Education and Counseling

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Abstract. When deployed on smartphones, virtual agents have the potential to deliver life-saving advice regarding emergency medical conditions, as well as provide a convenient channel for health education to help improve the safety and efficacy of pharmacotherapy. This paper describes the use of a smartphone-based virtual agent that provides counseling to patients with Atrial Fibrillation, along with the results from a pilot acceptance study among patients with the condition. Atrial Fibrillation is a highly prevalent heart rhythm disorder and is known to significantly increase the risk of stroke, heart failure and death. In this study, a virtual agent is deployed in conjunction with a smartphone-based heart rhythm monitor that lets patients obtain real-time diagnostic information on the status of their atrial fibrillation and determine whether immediate action may be needed. The results of the study indicate that participants are satisfied with receiving information about Atrial Fibrillation via the virtual agent.

Keywords: relational agent, cardiovascular, conversational agent, atrial fibrillation, heart rhythm.

1 Introduction

Smartphones are becoming ubiquitous, with the portion of US adults who own one steadily increasing (currently at 68%) while ownership of laptop and desktop computers is dropping [1]. Though virtual agents on smartphones lack the sense of presence and immersion that a large display can offer, smartphones provide a platform that is available anytime, anywhere, and will soon become the primary platform for deploying technology-based consumer health interventions.

In addition to their convenience, smartphones also provide a crucial affordance for time-critical applications; they provide immediate access regardless of where users are or what they might be doing. For certain health conditions, easy access to information may serve a critical role for real-time diagnosis, reinforcement of time-sensitive self-care activities (e.g., please take medicine X right now) and help link patients with their providers.

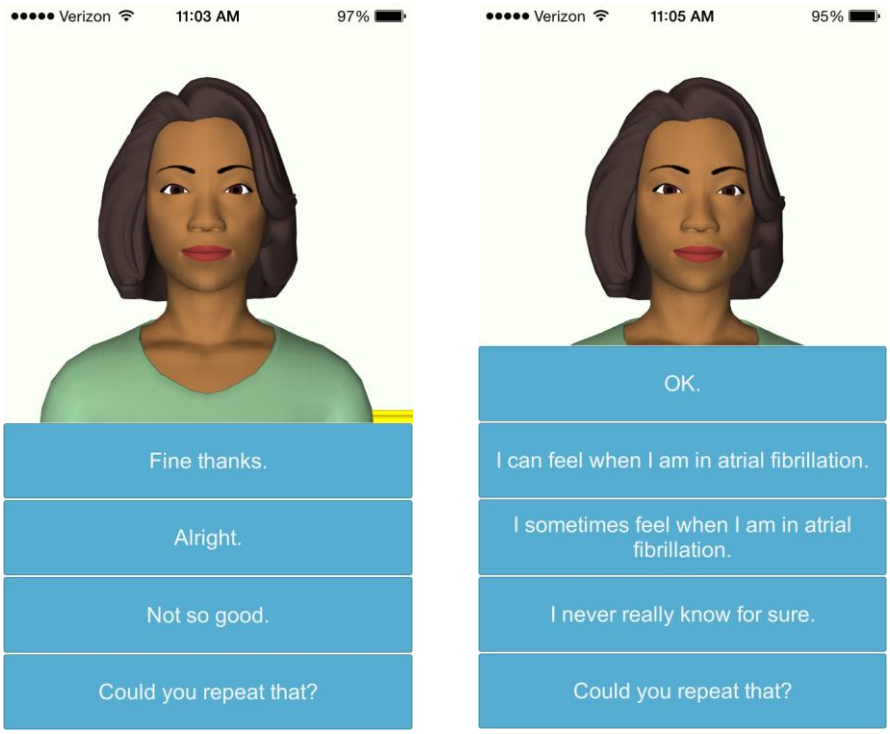

Fig. 1. Atrial Fibrillation Counselor Agent on iPhone

Atrial fibrillation (AF) is a highly prevalent irregular heart rhythm that is associated with adverse clinical outcomes, such as stroke. AF will afflict 6-12 million people in the US by 2050 [2, 3]—and is associated with a 2- to 5-fold increased risk of stroke, heart failure, and death [4-7]. AF requires adherence to medications for stroke prevention, symptom assessment and monitoring. One of the new approaches in managing AF involves the use of a mobile heart rhythm (EKG) monitor (Figure 2) which takes a 30-second snapshot of the user's heart rhythm and transmits it to a service that automatically analyzes it for AF and related parameters such as heart rate. It also makes this snapshot available for review by clinicians. The AliveCor heart monitor has been validated for use in detecting AF in a previous study [3]. Daily heart rhythm readings can help clinicians better manage patients with AF, and a patient experiencing symptoms such as heart palpitations or shortness of breath can take an immediate reading to help determine whether they need to adjust their activities, medications, or seek prompt medical care.

AF is a clinically complex condition where the heart rhythm can be intermittent. People are generally unaware of whether they are at risk of AF because they may not experience common symptoms such as palpitations, chest pains or even shortness of breath. In such cases, the heart rhythm monitor is crucial in detecting AF. However, as with all chronic conditions, adherence to recommended self-care procedures—such

Fig. 2. Mobile Heart Rhythm Monitor from AliveCor

as taking daily heart rhythm readings—can be challenging for many patients to maintain.

We have developed a virtual agent that plays the role of an advisor in educating patients about AF. The agent answers frequently-asked questions, collects regular self-reported symptoms and quality of life assessments, motivates adherence to AF-related medications and encourages patients to take regular heart rhythm readings (Figure 1). The agent is deployed on a smartphone so that it can be used whenever a patient is experiencing symptoms, and can motivate real-time heart rhythm readings when used in conjunction with a mobile heart rhythm monitor. The overall goals of the agent system are to reduce AF-related symptoms, improve medication and appointment adherence, decrease emergency room visits, and increase overall quality of life for patients living with AF.

The rest of this paper briefly reviews related work in this area, before describing the design of our virtual AF advisor. Then we present the results of a pilot test with AF patients and offer our conclusion.

2 Related Work

A number of virtual agents have now been developed to counsel patients on health problems, in general, and chronic disease self-care, in particular [8]. Agents have also been developed to provide one-on-one counseling to patients in areas like exercise promotion [9], weight loss [10], breastfeeding [11] and preconception care [12], with generally positive results. Additionally, virtual agents have proven to be effective in communicating complex health information to patients with low or inadequate health literacy [13].

Of particular relevance to this study are prior projects deploying virtual agents on mobile devices. Bickmore, et al, investigated the use of a virtual exercise counselor agent on a PDA device with integrated pedometer [14]. Design studies demonstrated that an animated virtual agent on a handheld device was more effective at building trust with users than equivalent static agent images or text-only interfaces [15]. Kang,

et al, describe a similar study investigating user reactions to an animated virtual agent on a smartphone as compared to a static agent image or no image, and find that users conducted longer conversations with the animated agent [16]. Leuski, et al, describe a virtual animated agent on a smartphone that helps diagnose medical conditions, although the system described is an incomplete concept demonstration [17].

3 Smartphone-based Virtual Agent

We developed a framework for deploying animated virtual agents on smartphones (Figure 1). The framework consists of three components: a commercial text-to-speech engine, an agent controller that synchronizes non-verbal behavior to synthesized speech, and a custom hierarchical transition network-based dialogue engine. Built using the Unity game engine, the agent controller is capable of synchronizing speech generated by the CereVoice commercial speech synthesizer to a variety of non-verbal conversational behaviors on a humanoid character. These non-verbal behaviors include: beat (baton) hand gestures and eyebrow raises for emphasis; a range of iconic/emblematic/deictic hand gestures; gaze away behavior for signaling turn-taking; facial displays of affect; and posture shifts to mark topic boundaries.

The dialogue engine consists of a custom hierarchical transition network-based engine that uses an XML-based scripting language to control the virtual agent's verbal and non-verbal behavior (Figure 3). Each dialogue state in this language consists of one or more of the following elements: "*speech*" to control the agent's utterances and non-verbal behavior; "*button*" to prompt the user for input via the presentation of multiple response utterance options; or "*compute*" to run arbitrary procedural attachments using data collected during the user's interaction with the system. Additional non-verbal conversational behavior, such as eyebrow raises and beat gestures, are automatically added to each script during a compilation process using BEAT [18]. Utterances can be tailored at runtime using template-based text generation [19], as exemplified by the *"[Name]"* syntax in Figure 3, which inserts the user's given name into the agent utterance before it is sent to the speech synthesizer.

```
<script>
  <state name="Greeting">
      <speech>Hi! How are you doing today?</speech>
      <buttons>
          <button nextState="Positive">Great!</button>
          <button nextState="SmartResponse">I've felt better</button>
      </buttons>
  </state>
  <state name="SmartResponse">
      <speech>I'm sorry to hear that [Name], I hope you feel better</speech>
      <compute function="DecideNextState"/>
  </state>
</script>
```

Fig. 3. Example XML Script

For use in the AF counseling system, a racially ambiguous female agent was designed based on feedback from patient interviews and focus groups.

4 Atrial Fibrillation Counseling

The AF counselor agent is designed to be used as a clinical intervention for patients recently diagnosed with AF. Patient-agent interactions are flexible and primarily user-directed to allow for patient-specific responses. During the first week of the intervention, the counselor prioritizes education in its dialog, explaining what AF is, how to effectively use the heart rhythm monitor, and describing common symptoms associated with the condition.

Over long term use, the agent promotes adherence to daily heart rhythm monitor readings. For example, the agent asks, "So, have you taken an AliveCor reading since we last talked?" or say, "I understand. Life can get in the way. Don't forget, it's important to take at least one reading a day, and whenever you feel you need to." As a reminder the agent would say "As soon as we are finished with our chat, please take a reading to send to the research team." The agent also promotes adherence to AF-related medications and clinic appointments.

Furthermore, the agent asks the patient to report symptoms associated with AF—such as palpitations, dizziness, and fatigue—as well as side effects such as bleeding from blood thinning medications. The agent tracks intervention outcomes by periodically asking patients for quality of life assessments. Feedback on self-reported patient information is based on both absolute ratings ("Sorry to hear you're not feeling well"), and longitudinal changes ("Looks like things are improving!").

5 Pilot Evaluation Study

We conducted a pilot study to evaluate the acceptance of our smartphone based AF counseling application among adults with non-valvular atrial fibrillation who owned an iPhone. With participant consent, we installed the agent and AliveCor applications on their phones and asked them to take the system home for a one-week evaluation before returning to the clinic to report on their experience.

5.1 Participants

We recruited participants from Boston University Medical Center for our pilot study. Participants were required to be 18 years of age or older; English speaking, in possession of an iPhone, and able to independently consent to participate in the project. A total of 16 participants (5 females, 11 males), between the ages of 20 to 58 (M = 40), took part in the study. 11 of the 16 participants (3 with AF) completed our satisfaction questionnaire. 3 of the participants included in the study had AF and one of 3 who had

AF also had Wolf Parkinson White syndrome. The rest of the participants acted as controls to evaluate the usability and functionality of the system.

5.2 Measures

We used a self-report scale measures to evaluate overall satisfaction of participants with our smartphone based AF-focused agent (Table 1). We also conducted a semi-

Table 1. Self-Report Ratings of Agent and AliveCor Heart Rhythm Monitor (mean (sd))

Question	Anchor 1	Anchor 4	Agent (N=11)
How satisfied were you with the agent?	Not at all	Very satisfied	3.45 (0.52)
How easy was talking to the agent?	Very difficult	Very easy	3.54 (0.69)
How much would you like to continue working with the agent on other aspects of atrial fibrillation?	Not at all	Very much	2.82 (1.08)
How would you describe your relationship with the agent?	Complete stranger	Close Friend	2.18 (1.08)
How helpful was the agent to you?	Not at all helpful	Very helpful	2.82 (0.98)
How satisfied were you with the AliveCor heart rhythm monitor?	Not at all	Very satisfied	3.54 (0.52)
How easy was using the AliveCor heart rhythm monitor?	Very difficult	Very easy	3.54 (0.52)
How much would you like to continue using the AliveCor heart rhythm monitor?	Not at all	Very much	3.18 (0.87)
How helpful was the AliveCor heart rhythm monitor?	Not at all	Very helpful	3.00 (0.95)

structured interview with the participants to determine how long they interacted with the agent and their reaction to the agent and AF content.

5.3 Results

Participants reported a 7 to 10-minute-long interaction with the agent each day. Older participants reported longer interactions and found agent feedback to be relevant to their condition.

Most participants reported high overall satisfaction with the agent (M = 3.45 on a 4-point scale), as well as high ratings for ease of use (M = 3.54). They also reported high levels of satisfaction with the AliveCor heart rhythm monitor (M = 3.54).

6 Conclusion

This study demonstrates the feasibility of delivering atrial fibrillation counseling via a virtual agent on smartphones. Participants in our study found the AF information to be helpful and were relatively satisfied with their interaction with the agent. The reported satisfaction with the agent correlated with the participants' satisfaction with the use of AliveCor heart rhythm monitor.

6.1 Future Work

Currently, we are completing work on a more comprehensive AF intervention prior to launching a randomized, controlled trial to thoroughly evaluate the system. Future versions of the AF counseling system will integrate information from the heart rhythm monitor so the agent will know when a user has taken a reading and the nature of any diagnostic information provided by a clinician who has reviewed the EKG readings.

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