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Challenges in Creating a Mobile Digital Tutor for Clinical Communications Training

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Abstract

Doctor-patient communication is a crucial element in effective medical care, and the striking health disparities evident in patients with Type II Diabetes may in part be caused by physicians' difficulties in establishing effective communication with patients who differ from them racially, culturally, and economically. REPEAT (Realizing Enhanced Patient Encounters through Aiding and Training) is a digital tutor developed to help solve this problem. REPEAT teaches and coaches learners to improve their general and disparities-focused clinical communication skills using simulated encounters with computer-generated Synthetic Standardized Patients (SSPs) and augments experiential learning in virtual encounters by applying customized, context-sensitive, learner-focused scaffolding. REPEAT authoring tools enable rapid development of learning content, allowing economical transferability to other domains. Key human factors challenges and their design solution in REPEAT are discussed.

Keywords

Digital tutor; Clinical communications; Mobile Game-based training; Intelligent tutoring; Health disparities

1 Introduction

Diabetes mellitus is a chronic metabolic disease that affects an estimated 29.1 million children and adults in the US alone [1, 2]. Type II Diabetes (T2D), the most common form, demonstrates striking health disparities in both health outcomes and healthcare quality, with minorities more than 70% more likely to be diagnosed and much more likely to experience complications [3]. Healthcare disparities have been linked, in part, to physicians' difficulties in establishing effective communication with patients who differ from them in terms of gender, age, race, ethnicity and culture [4]. Doctor-patient communication is a crucial element in effective medical care, and diabetes-related complications and poor health

outcomes that are often attributed to *non-adherence* (or *non-compliance*)—e.g., failure to make lifestyle changes or follow physician recommendations—may be more accurately viewed as a doctor-patient communication problem [5].

Current medical training practices in communication skills and associated content—such as disparities-related communication competence—rely heavily on traditional didactic instruction, traditional apprenticeship (e.g., internship and residency), and the use of occasional simulated encounters with actors playing the patient role, commonly called Standardized Patients (SPs). Didactic instruction is unlikely to lead to long-term change in clinical behavior without follow-up practice. Apprenticeship allows the learner to observe and practice, but often without standards-based assessment. Live role-play with SPs, combined with individualized critique from instructors, allows for such practice, but is expensive, constrained by cost and availability of SPs, and not scalable to universal use.

A viable alternative to live SP encounters can be found in work associated with scenario-based training (SBT) [6, 7] and digital tutoring [8, 9]. SBT is an approach to experiential training that engages the learner in repeated authentic practice opportunities using state-of-the-art modeling and simulation technologies [10]. Based on extensive findings from the science of learning and human performance, SBT is based on the notion that expertise is developed as learners are exposed to many examples of a task or situation [6]. Using simulation for training in the more technical aspects of medicine (e.g., surgery) is quite common [11, 12]. However, use of simulation and scenario-based training in other areas of medical training has lagged, due in part to complexity in modeling human-to-human interactions. Digital tutoring, sometimes termed intelligent tutoring, takes the approach of SBT one step further by seeking to integrate a model of a one-on-one human tutor into the simulated practice environment. It does this by providing individualized in-practice instruction, in the form of coaching and feedback (and other forms of scaffolding) that is adapted to the individual learner based on a dynamically updated model of the state of the learner's acquisition of the targeted knowledge.

To address the problem of helping improve physicians' clinical communication skills in treating T2D patients who differ from them racially, culturally, and economically, we have developed a digital tutor called REPEAT (Realizing Enhanced Patient Encounters through Aiding and Training).

2 Key Human Factors Challenges in Designing REPEAT

REPEAT teaches and coaches learners to improve their general and disparities-focused clinical communication skills in treating patients with T2D. It provides didactic instruction, and then tutors learners' communication skill through practice in simulated encounters with computer-generated Synthetic Standardized Patients (SSPs). It enhances experiential learning in virtual encounters by applying customized, learner-focused scaffolding that is context-sensitive to learner actions. REPEAT authoring tools enable rapid and easy development/editing of learning content, allowing economical transferability to other clinical and even non-clinical domains.

There were multiple challenges encountered in the design of REPEAT. Some of these were specific to the clinical communications domain, while others were related to the problem of providing training (in general) and creating digital tutors (in particular) for inter-personal interaction and communications skills. And still others arose from underlying social and economic issues underlying health disparities. Below, we discuss five of these challenges, followed by a summary of how they were addressed in the design and development of REPEAT.

2.1 The Clinical Encounter Is Neither Symmetrical nor Necessarily Collaborative

The clinical encounter between health-care provider (typically a physician, though the two terms are used interchangeably here) and patient is a face-to-face interaction that largely consists of the two parties talking to each other [13], although neither in a casual manner (as in everyday conversation) nor in a structured teamwork manner (as in communications between an aircraft pilot and an air traffic controller). Rather, the interaction is highly purposive — specifically towards discussing the health of the patient, most often with regards to a specific health problem — and broadly structured by many factors, including the specifics of the health problem. While the purpose of the visit may be shared between provider and patient, however, the structure and dynamics of the interaction are asymmetrical and the goals of the interacting parties are frequently different and sometimes even divergent.

The asymmetry begins with the encounter setting. The encounter typically takes place in the everyday (and familiar) workplace of the provider, which to the patient is often an unfamiliar and uncomfortable setting, and frequently associated with emotions of discomfort or fear. The physician has more control than the patient has in establishing the agenda and flow of the interaction, and in controlling its pacing and termination. This can be perceived as a power differential, particularly for patients from low-income and/or marginalized populations, who often bring both personal histories and expectations of discriminatory interactions in situations where there is a high power-differential. At the same time, the physician may perceive having much less control over the content of an encounter than it would seem to the patient. For example, encounters must address certain topics and cover certain data points, or they either cannot be billed or will be marked as a “low quality” encounter. Such dictums and constraints are the result of large-scale policy, organizational, and economic forces that are beyond the control of the provider (or the patient).

The goals of the participants converge at the highest level on resolving the patient’s health problem, but at lower levels and on dimensions such as economics of the visit and the treatment plan, the goals of the parties can and often do differ. Patients, for example, bring goals and concerns to the interaction that reflect issues of their lives outside the encounter. These include:

- financial concerns, ranging from the cost of the treatment plan to the plan’s and the health condition’s impact on their ability to work and earn money; and
- social concerns, such as the patient’s ability to fulfill internalized responsibilities to care for or provide for family members.

Again, when the patient is low-income or marginalized, the broader problems of limited access to education, employment, housing, transportation and even food, become intertwined with concerns about health and treatment [14] that affect the patient's goals for the encounter.

Analogously, the provider brings goals and constraints to the encounter that affect the structure of the interaction. These include concerns about the economics of daily workflow and the time that can be reasonably spent with each patient, regulatory and organization requirements and prohibitions, concerns for liability and litigation exposure, among others. Beyond these divergent goals and concerns, there are also underlying concerns about biases, implicit and explicit from providers, and expectations of bias (whether warranted or not) on the part of patients.

Together, the complexities of these clinical encounters for low-income/minority patients create a substantial challenge for crafting virtual encounters in REPEAT that can be both realistic and designed so as to provide a clear opportunity for development of improved communication skills on the part of providers.

2.2 Communication Skills Involve Diffuse Knowledge

The communications skills that are needed to improve clinical communications are themselves another challenge. Much of digital tutoring research has focused on problem areas in which the underlying knowledge is well defined and unambiguous its application (e.g., mathematics or physics problem solving, programming), e.g., [15]. However, the knowledge needed to draw out unexpressed patient issues and to adaptively apply that understanding of those issues in an encounter, certainly does not have these properties (or at least our understanding of the underlying knowledge is insufficiently advanced to be able to express in the same precise manner as rules of math or physics). Rather, the knowledge and skills needed are understood at much more abstract levels, in terms of constructs such as active listening skills or empathetic skills. Such abstracted skill definitions are not tied at all to specific knowledge elements that a learner must acquire and apply in order to acquire and improve those skills.

The vague definition of the skills makes them difficult to teach, difficult to learn, and perhaps most importantly, difficult to assess. These limitations, in turn, make it challenging to develop provider-SSP dialogs for REPEAT that lead to clear applications of the desired underlying knowledge and skills, that can be automatically assessed by the software, and that can be demonstrated to transfer to live interaction settings.

2.3 Patient Variability Drives the Learning Opportunities

There are many concerns and issues that individual patients bring to a clinical encounter, and that affect each patient's goals and approach in the encounter. To the extent that many of these concerns and issues are based on larger socio-economic problems, providers have to deal with similar problems and concerns repeatedly, but each time cloaked within the unique situation of each patient. Still, however, the specific factors that affect each individual encounter are unique to each individual patient and remain invisible with each patient until exposed through the dialog in the interaction, whether general (as in lack of insurance) or

unique (as with an elderly dependent living in the patient's house). Once the relevant factors affecting that specific patient are made known, the provider must then be able to determine how each could and should be factored in that patient's treatment plan.

Since each patient brings both common and unique challenges, providers using REPEAT to develop and hone these skills through virtual practice need to have access to a sample of virtual patients that are, at the same time, realistic individually and representative collectively of a specific population. Developing such a sample of virtual patients with regard to a reference population and the health barriers which that population faces presented another challenge to REPEAT design.

2.4 Context and Flow Are Critical in the Interaction

Providing for appropriate and realistic variability across the set of patients that a REPEAT learner will encounter is important because that learner must develop communication skills that can be applied the full range of patients that she or he will encounter in the clinical 'real world.' But creating this variability in the virtual patient population is not enough by itself. The dialogs in the REPEAT encounters must also be designed and manipulated so as to allow for the unique set of concerns, health barriers, and constraints for a given patient—the patient's backstory—to affect the course of that dialog in a believable and appropriate manner. The patient's backstory contains elements of information that must be discovered by the learner in the interaction and recognized in terms of their relevance to the patient's treatment and self-management plan for the patient's T2D. Such details of the patients' backstory, once exposed in the dialog, then become context for future evolutions of the interaction, both for the physician and by the patient.

For example, consider a patient who is unemployed and does not own a car or live near public transportation. These are factors that can affect that patient's ability to afford additional medications or to travel to treatment sites (e.g., for physical therapy) that are not very near to her home, but the patient may not expose this information spontaneously to the physician. Instead, the physician must use learned communication skills to probe and identify the existence of such barriers, exposing these as elements of context for the encounter. Failing to apply those skills successfully would leave those issues unexposed, and leave the learner unable to tailor the treatment plan to the exposed context elements. Additionally, even if exposed, the learner might remain aware of these context elements at that later point in time and still fail to appropriately use this exposed context information in the treatment plan development. Further, in this latter situation, the patient may become upset or discouraged at what is perceived as the physicians not caring about the information, or forgetting it quickly. These feelings can then negatively affect the patient's participation in the dialog going forward. For REPEAT to be effective, the dialogs within the virtual encounters need to be constructed or controlled in a way that ensures that all such context-sensitive evolutions are available.

2.5 Natural Language Interaction Is Not (yet) and an Option

The ideal form of the dialog in a REPEAT virtual encounter is through unconstrained spoken natural language. This is the mode of interaction that the learner will use in live encounters,

and one that should create not interactive ‘friction’ between the learner and the digital tutor. However, the reality is that the current technology is not yet close to being able to support this form of interaction, for multiple reasons. These include the need for virtually 100% accuracy in recognition, the need for completely understandable computer-generated speech, and the need to be able to construct extended robust dialogs that are based on the unique backstories of different simulated characters. None of these is within the capabilities of the current state of the art (see [16]). Thus, the complex constraints on the provider-patient dialogs described earlier in this section had to be met with more constrained approaches to the verbal interaction.

3 Design Solutions in REPEAT

The design for REPEAT addressed each of the challenges and issues discussed above. Because REPEAT is, above all else, an instructional system, the highest level design decisions concern what specifically would be the learning objectives and how learner progress against those objectives would be assessed. These decisions were informed by developments resulting from the increased concern with clinical communication in the 21st century (see [13: preface to 2nd Edition]) in research, policy and medical education communities. Of main relevance to the development of learning objectives were the Core Entrustable Professional Activities (EPA) for Entering Residency (CEPAR) developed by the Association of Academic Medical Colleges [17]. EPA 1, “Gather a history and perform a physical exam”, was used as the key integration point between REPEAT and CEPAR along with four specific competencies required for developing cognitive and communicative skills necessary to EPA 1. The four specific competencies were then tailored to the REPEAT focus on low-income African American T2D patients. From this basis, learning objectives were then defined from these desired competencies, from using the Reporter-Interpreter-Manager Education (RIME) model in medical education [18, 19], where new learners are expected to gather and report information accurately and more advanced learners are expected to educate patients and other learners. Three specific curricular units were also defined, corresponding to the three RIME level (R,I,M/E).

For the assessment of skills on these objectives, an independent measurement scale was used and adapted for both assessment of behavior against the learning objectives within a virtual encounter and in live encounters, thus providing a common measure for instructional assessment and transfer of learning assessment. This was the Macy Communication Scale for provider-patient communications [20]. As with the RIME-based objectives, the MACY-based assessment scale had to be adapted to the health disparities context of the curriculum. One further extension of the assessment scale had to be developed as well, that of support for encounter authoring. The creation of encounter scripts (discussed below) required the definition of choice points in the encounter where a learner needed to chose a path forward from among finite options. These choice points were linked with learning objectives (one or two per choice point), with different options representing positive or failed application of the skill associated with the learning objectives. The relevant elements of the MACY-based within-encounter assessment scale were, in essence, reverse engineered to provide guidance to the choice-authors on how to craft choices that were either good or bad with regard to

each applicable objective. This guidance helped authors create choice options that were both consistent with the objectives and with the assessment scale.

The problem of creating a realistic and representative set of patients for the REPEAT practice encounters was addressed using a method called Backstory Elaboration [21] created earlier in REPEAT development. Backstory Elaboration uses a structured process, informed by social/behavioral science data on the population being represented, to create a set of characters with individual and unique backstories. Each backstory includes specific values from relevant socio-demographic, medical, and psycho-social variables that are also integrated into a narrative that is the literal backstory. The backstory narrative and set of specific variable characteristics were then used to create an appropriate on-screen avatar for the character, and were used to build out the dialog for that patient in a specific encounter.

The remaining design challenges all concerned the representation and engineering of the provider-patient dialog within a given encounter. The encounter dialog had to support the structural constraints required by the medical purposes of the visit, allow substantial openness in the possible evolutions of the interaction given the patient's backstory and the context factors that they afforded, and allow the full range of knowledge and skill that the learner could employ in conversing with the patient. The dialog also had to be engineered to offer options to the learner that could be effectively mapped into learning objectives and could change depending on the degree to which the relevant patient context was successfully exposed. Plus, as noted above, it could not rely on open-ended natural language interactions.

The design decision for this key aspect of REPEAT was to represent each encounter as a network of possible dialog transactions. The dialog nets were designed around a basic dyadic turn-taking transaction as a fundamental building block – a simple ordered pair of “character 1 says something and character 2 says something back” – and multiple layers of structure. At the most abstract level, the dialog was structured into segments that created a macro workflow for the encounter. The workflow was defined by the type of the encounter, (e.g., initial diagnosis of T2D, follow-up visit for a diagnosed patient, follow-up visit for diagnosed patient with a specific type of complication, etc.).

Within each segment, the next layer of structure added the dialog details. A dialog flow was created within each segment as a combination of linear sequences of transactions and choice points for the learner. The choice points were created at points in the dialog flow where the learner had to apply (or fail to apply) specific knowledge and skills to the choice of the next thing to say to the patient. Each choice point was linked to one or two learning objectives for the specific unit of the course, and structured to pose different combinations of success/failure on the linked objectives (e.g., for two objective there could be a ++ option a +/- option, etc.). The specific dialogs for each option were authored using the objective-anchored authoring guidance discussed above. The branches created by the options could continue through the current segment or even branch further, but had to be reunited at the transition to the next segment of the encounter.

At the next level of structure the learner assessment was added. When a learner made a specific decision at a choice point, the objective $\pm$ ratings of the chosen option were

provided to the REPEAT student model. That model kept a dynamic estimate of the learner's knowledge state on each objective, and updated it after each learner choice. It then used that updated estimate to determine which form and content of scaffolding (e.g., level of feedback) was appropriate for that learner given the just-made choice.

Thus the dialog network structure allowed flexibility and variability and linkage to assessment and scaffolding, as desired. However, the basic dialog network became a stateless process at each convergence point at the transition from one segment of the encounter to another, and therefore had no way to deal with exposed context information or to propagate it forward. This capability was added at the final level of the dialog net using a novel method. At this level, context metatag information was attached to specific utterances within transaction nodes on a dialog tree at which context information was exposed into the dialog. The metatags identified the specific context information exposed, and were organized according to the variables that were included in the patient's backstory (as established in the Backstory Elaboration analysis). The metatags were processed by a novel component of REPEAT called the context cart. Like the shopping cart in an e-commerce app, the context cart collected information that could be passed forward to future steps in an otherwise stateless process. Thus, if a piece of context were exposed in a specific patient dialog utterance, its metatag would be placed into the context cart. At later points in the encounter, the presence/absence of that piece of context could be detected by REPEAT, and used in customizing the choice options, e.g., by presenting or hiding specific dialog options.

A virtual encounter in REPEAT could therefore be represented in single complete dialog network. This full dialog network was then translated into a data structure that could be used by a computer game engine to express the encounter as an on-screen game that paused for learner input at each choice option point reached, and provided customized adaptive tutoring information as provided by the REPEAT student model that worked in tandem with the game engine.

One final decision in REPEAT was the mechanism used to deliver the training. Virtually all prior virtual tutors and simulation-based training had been designed for delivery on a desktop or laptop computer. However, we wanted to make REPEAT available for anytime, anywhere usage, and the end-user analysis of our target population (medical students and residents as well as practicing physicians) suggested that the device that was constantly available was neither a laptop or desktop machine, but rather a smart phone. Thus, we developed REPEAT to be entirely accessed through a learner's smartphone.

4 Overview of the REPEAT System

The heart of REPEAT is the REPEAT app, through which a learner accesses REPEAT courses. This app can be downloaded in any Android or iOS smart phone or tablet. The app itself is built using the Unity 3D game development toolset, but within that app all the elements of tutoring – learner modeling, management of scaffolding to the learner based on the curriculum and the specific learner's modeled knowledge state, and context management – are done through an embedded subsystem built outside of Unity 3D. In comparison, the main UNITY component processes the script for the encounter as an interactive game, and

controls input from and output to the learner, both within a practice encounter, and outside the encounter. The outside-the-encounter functionality includes selection and execution of specific courses, course units, and practice encounters within a unit, as well as access to didactic instruction at the course-unit level. It also includes access to and presentation of displays on the learner's progress through the curriculum, by objective.

When the learner accesses a course, the course material is downloaded from the REPEAT back-end server onto the learner's device, and the learner can access, leave, and return to the app at any time. As the learner progresses through specific units, and takes part in virtual practice encounters with different simulated counselees, data on the learner's performance is sent to the REPEAT back-end server for storage and analysis. Simultaneously, the virtual tutor within the app provides the learner with scaffolding (forms of instructional support) designed to improve and shorten the learner's time to achieve competence in each skill taught by that course.

The REPEAT back-end services also support interaction with and manage access to various databases with the learning materials (e.g., course structure, didactics, practice scenarios) for each REPEAT course, and with all the performance state of each learner on each course, as defined by the most recent of the student model for that learner/course combination. Performance data on each choice made by each learner in each course offers the opportunity for more fine-grained analysis of learner progress as well as of the diagnosticity of specific choice-points across learners. Each such selection can be viewed as an individual learning experience [22] that can be captured as such and stored in a Learning Record Store system (LRS) [23]. REPEAT includes mechanisms to capture learning experiences and to export them to an external LRS. Existing LRSs 'both research and commercial' contain instructor-facing tools to analyze learning experience data.

The back-end services can also communicate with the Learning Management System (LMS) of a specific institution or organization, allowing that institution to authorize specific learners access to the course, and to receive each authorized learner's final performance data after course completion.

The learning materials, such as the objective structures, patient backstories, and the encounter scripts are created through a separate set of REPEAT Authoring Tools, via a web-based user interface to the REPEAT back-end services. The Authoring Tools also allow existing courses to be edited, extended, or 'cloned' as the starting point for new courses.

Finally, the back-end also provides an in-process web-based dashboard for training instructors or managers, allowing those individuals (authorized by the institution) to view individual learners progress data at a range of level of aggregation. This supports, for example, opportunities for blending the virtual learning with live classroom learning and discussion. Figure 1 depicts the logical architecture of the current REPEAT System.

5 Summary and Future Research

REPEAT (Realizing Enhanced Practice Experiences through Adaptive Tutoring), is a digital tutor designed to improve physicians' clinical communication skills in interacting with T2D patients from low-income minority populations. It does this by:

- allowing them to practice these skills in simulated encounters with computer-generated virtual patients, and
- guiding their virtual practice with customized, learner-focused scaffolding that is context-sensitive to learner actions and inferred skill level.

REPEAT was designed to deal with a range of challenges arising from the specific content-area, plus additional challenges associated with the need for anytime/anywhere access to practice and tutoring (which resulted in the delivery of the REPEAT curriculum through a smartphone app). Key content-domain challenges explicitly addressed in the REPEAT design include:

- participants in clinical interactions bringing overlapping (but not converging) and sometimes diverging goals to the interaction;
- incorporating the large variability in individual issues, histories, and concerns on the patient side that must be represented across practice encounters to give the learner a reasonable range of experience from which to learn;
- creating interactive sessions that can evolve in complex context-sensitive ways; and
- circumventing technology limits precluding the direct application of open-ended natural language processing technology.

These challenges are also common to other communications and 'soft skill' content domains, making the REPEAT approach and training delivery technology more broadly applicable. Current research is underway to assess the training efficacy of the REPEAT app and disparities communication curriculum, through a randomized control trial with graduate and undergraduate medical students. Futures research areas involve exploring the component and comparative value of different features of the training delivery design.

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Fig. 1.

Logical components and interconnections comprising the REPEAT system. The dashed lines around the LMS instructor portal indicate that it is a functionality provided by the local LMS and not from REPEAT.