Adapting with Evidence: The Adaptive Model and the Stimulation Plan of TERENCE

Mohammad Alrifai, Rosella Gennari, and Pierpaolo Vittorini

Abstract. TERENCE is an FP7 ICT European project that aims at developing an adaptive learning system for supporting learners and educators. The TERENCE learners are 7-8 to 11 year old children with poor reading comprehension skills. The TERENCE educators are primary-school teachers, support teachers and parents. This paper describes the stimulation plan for the TERENCE learners, based on clinical practice, and the adaptive learning model of TERENCE that stems from the stimulation plan. In other words, the design of the model follows the evidence based design.

1 Introduction

A *learning management system* (LMS) is a suite of functionalities designed to deliver, track, report on and manage learning content, learners' progress and learners' interactions. LMSs can apply to very simple course management systems, or highly complex enterprise-wide, distributed environments. Within LMSs, the ability to tailor instruction to individual and organisational needs become a crucial issue, thus leading to the development of the so-called *adaptive learning systems* (ALSs) [4]. Differently from the other LMSs, an ALS features the *adaptation engine* that actually personalises the learning process, based on the *adaptation model*.

TERENCE is a project that aims at designing and developing the first *adaptive learning system* (ALS) for poor comprehenders, i.e., primary school children that

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P. Vittorini et al. (Eds.): International Workshop on Evidence-Based TEL, AISC 152, pp. 75–82.
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have well developed low-level cognitive skills (e.g., word decoding), but that have problems with deep text comprehension [5, 7]. These are the TERENCE *learners*.

This paper focuses on the adaptation model of the TERENCE system for the TERENCE learners. The model has rules that formalise the stimulation plan for the learners, which is the other main contribution of this paper. The plan is based on clinical practice, and has been informally specified through brainstorming meetings with therapists expert of the TERENCE learners. In other words, the design of the adaptive model of TERENCE follows the *evidence based design* (EBD). This paper ends with a recap conclusive section.

2 Background

The conceptual model of the TERENCE ALS is modularised into (1) the user models, including the learner sub-model specifying and structuring the requirements of poor comprehenders, (2) a domain model that structures the learning material, (3) the adaptation model for the adaptation learning process, specifying the rules correlating concepts of the domain model and the user model. The user and domain models are only briefly sketched here, and more extensively described in [2].

The User Model. The user model has, as submodels, the model for the expert (e.g., psychologists), that for the educators and, most importantly, that for the learner, which structures the data concerning the TERENCE learners. The learner model also structures the so-called *reading comprehension* (RC) skills of a learner. Each RC skill has also different RC levels.

The Domain Model. The reading material of the TERENCE ALS is given by stories, in English and in Italian, adapted to the specific requirements of poor comprehenders. Stories are grouped into thematic coherent units, that is, books. The reading interventions of the system are interactive smart games centred around inference-making skills that foster the development of deep text comprehension of poor comprehenders; the interventions are rooted in the literature of psychologists and therapists working with poor comprehenders, as well as educators. See [3]. The books, stories and games are structured as in the domain model of the system. In particular, in the domain model of TERENCE, each story is associated to the RC skills, specified by the learner model, at a certain RC level. Moreover, each story is associated to a set of smart games. Each smart game serves to evaluate a specific RC skill.

The Adaptation Model. The adaptation model of an ALS is a set of rules that describes how knowledge stored and structured as in the user and domain models can be used for providing adaptive learning experience to the learners. In the remainder of this paper, we describe the adaptation model of the TERENCE ALS for the TERENCE learners. Firstly, we describe the evidence for the model, namely, the stimulation plan for the TERENCE learners. Then we move on to explain specific adaptation activities, based on the stimulation plan: the book and story recommendation; the book adaptation activities; the learner profile's update.

3 Stimulation Plan for Adaptation

The stimulation plan is mainly based on [6]. In the following, we give the essential ingredients of the stimulation plan, and that are turned into concepts of the adaptation model in the subsequent section.

3.1 Cycles and Sessions

A *session* of the stimulation plan consists in reading a story of a book, and then resolving the correlated games. Reading a story is a *reading activity*. Playing a game is a *playing activity*. In general, in a session, games are ordered as follows. First a subset of smart games is proposed. Then the learner plays with relaxing games, which are unrelated to the story and have a relaxing and distracting effect. Then, another subset of smart games is proposed.

Each week of the plan should foresee at least two or three sessions: the higher the number of sessions is in a week, the higher the number is of read stories and played games, the stronger the stimulation is.

A *cycle* consists of 2–3 sessions per week, lasting 2–3 months, with a brief suspension of c.a one week. The longer the cycles, the shorter the suspension, the stronger the stimulation. Evidence-based clinical practice suggests a suspension of circa 2 weeks. See also Fig. 1 for an example of a cycle of 2 months and 2 weeks, with 10 sessions.

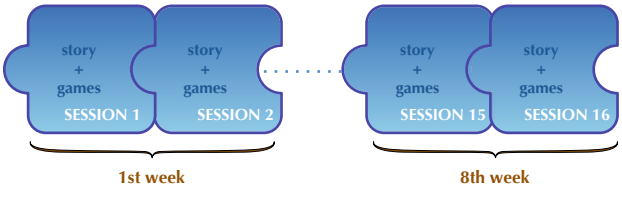

Fig. 1 A cycle of c.a 2 months and 2 weeks, divided into 10 sessions, each lasting one week

3.2 Measures of Activities

Reading and playing activities have different types of measures, described as follows.

The reading activity has diverse logged times. The *reading time* is the time spent by a learner in reading a story of a session, whereas the *maximum reading time* of a story is the maximum time allowed for reading the story, independently of the learner. The *average reading time* for a learner is the average of the reading times the learner has spent in reading stories across the already run sessions.

For the playing activity in a session, we should at least take care of two different types of measures: concerning time; concerning resolutions of games. As for time, when playing in a session, we have the following measures:

– the *resolution time* of a game in the session is the time spent by the learner for resolving the game;
– the *maximum resolution time* of a game in the session is the maximum time allowed for resolving the game, independently of the learner;
– the *average resolution time* for a learner in the session is the average of the resolution times the learner has so far taken for resolving the played games of the session.

All are updated after playing with a game. As for the resolutions of a learner, while playing in a session, we have the following measures for the session's games that evaluate a certain RC skill:

– the *accuracy* ratio is the number of games for that RC skill correctly resolved so far in the session, divided by the total number of games for that RC skill so far played;
– the *omission* ratio is the number of games for that RC skill that are so-far skipped or unresolved within the maximum resolution time in the session, divided by the total number of games for that RC skill so far played.

Given the aforementioned measures, clinical practice suggests that, at the end of a session, we can improve and update the learner's RC level of the RC skill evaluated by the played smart games if

1. the omission ratio decreases, and the accuracy ratio increases,
2. possibly, the average resolution time decreases, and the average reading time decreases.

3.3 Smart Games and Sessions

Smart games should address the story's events in the same order in which these are presented in the story. For each RC skill, the RC level of a story and games in the first session should be the same as the learner's RC level, or even slightly inferior than this, so as not to frustrate the learner. According to the updates to the learner's RC skill at the end of a session, the system can then increase the related RC level of the story and games in the subsequent sessions.

The first session is likely to be slightly different than the subsequent sessions, because in that session the learners need to acquaint with the system. Accordingly, the first session will mainly consist of the training to the system. For instance, the learner will get familiar with the system's interface, and the type of interactions required by the TERENCE games. In particular, the resolution times during the first session and the accuracy ratio are likely to depend on the concurrent training with the system. During the other sessions, the resolution times of the session's games should become independent from this aspect.

If, in a session, the learner makes a significant number of mistakes in resolving the smart games of the story (that is, the learner's accuracy is low or the learner's omission is high), the system:

– shall propose the same story in a simplified version in a subsequent session with the system;
– shall propose easier games, or games with other feedback than the correctness of the resolution.

Another important part of the stimulation consists indeed in the feedback to the resolution of a game, which is adapted to the learner and the session. In the first session, the only feedback is a so-called consistency feedback, textually and visually given: yes, the resolution is correct; no, it is not. In the later sessions, the feedback can change according to the profile of the learner. For instance, if in the previous session the learner had a low profile in a certain type of games, the feedback to the resolution of the same type of games in the current session will be of type explanatory, offering cues for resolving the game in case the learner's time in resolving the game is higher than the maximum resolution time.

4 From the Stimulation Plan to the Adaptation Model

The stimulation plan lends itself naturally to the design of the adaptation model of the TERENCE ALS. In particular, it provides information for the recommendation of books to the learner, for the navigation of the book's stories, for the update of the learner's profile according to the RC skill measured by certain smart games in a session with the system. In this section, we consider each of such issues separately.

4.1 Recommendation of Books

The TERENCE ALS is capable of recommending adequate books for the learner by matching concepts and data related to the book model with concepts and data related to the learner. As for this, relevant concepts are the learner's interest, preferences and demographic characteristics, structured as in the learner model.

4.2 Navigation of a Book

Traditionally, in game design, a linear book has a linear narrative plot: stories of the book are related through a finite linear order. Instead, a branching book has got several branching narrative plots. A branching book can thus be associated to a rooted *directed acyclic graph* (DAG). The root of the DAG is labelled by the starting story of the book, and the ending stories label the leaves. Each node in the DAG is a story, i.e., a small self-contained part of the whole book. An edge from story x to story y in this rooted DAG means that reading story x is required to have an access to story y. See [1].

The logical design of the TERENCE books follows a branching book design. However, in a TERENCE branching book, each story is available in different versions. Each version is associated to a different RC level. The root of the DAG associated to a TERENCE book is labelled with the version of the starting story having

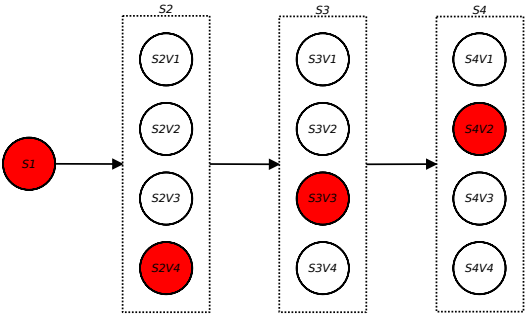

Fig. 2 The branching structure of a TERENCE book

the RC level expected for the learner. The DAG is then structured in layers: the nodes of the n-th layer are each labelled by a different version of the same story, starting from that at RC level 1. We have only the following constraint on the edges of the DAG of the TERENCE books: edges are from nodes of layer n to nodes of layer $n + 1$.

The learner, instead, is shown only a branch of the DAG. This means that the learner experiences a linear book, with a starting story and a final one. Moreover, in each session, the learner is shown only the versions of the still unread stories at his or her RC level. At the interface layer, the learners sees a pictorial representation of the branch: the nodes of the branch, that is, the different versions of the available stories of the book at his or her level, are visualised by showing the stories' environments.

Fig. 2 shows a simple case with four stories, and hence four layers in the DAG. The book starts with the first story S_1 at the expected RC level; this labels the root of the DAG of the book. Then, the second story S_2 is made available in four versions, i.e., $S_2V_1, S_2V_2, S_2V_3, S_2V_4$; each of this four versions labels a different node at layer 1. Similarly for the others. From the first story, depending on the profile of the learners, the adaptation consists in providing the learner with the version of the second story that matches the learners' current RC level. The red nodes show a path throw the DAG, and corresponds to the linearisation of the branching book that the learner experiences right after choosing the book.

Such a branching book design allows the learner to have a story adapted to the learner's RC level at every session.

4.3 The Learner Profile's Update

As the learners' RC skills can change during the learning process lifecycle, their profiles must reflect such changes. Therefore, the TERENCE ALS keeps track of the data of the learners' interactions with the system, and updates the learners' profiles accordingly.

The games in TERENCE are designed for assessing an RC level, or for relaxing. Therefore, a key interaction that influences the learner's profile is the game playing

activity. In line with the stimulation plan of Sect. 3, when the system observes that, at the end of a session, a learner has demonstrated a progress in resolving the games with an RC difficulty level not inferior to his or her currently stored level, the system updates the learner's level for this particular RC skill accordingly.

Notice that updating the RC skills of a learner automatically triggers an adaptation of the book's stories, that is, which versions of the stories should appear along the path that the learner is shown, as described above in Subsect. 4.2.

Moreover, by solving a game successfully, that is, by increasing his or her accuracy rate in a session, a learner gains points, which in turn leads to updating the score of the learner's avatar, that is, the learner's virtual representation, at the end of the session.

Fig. 3 shows some of the key concepts and attributes that are involved in this adaptation process in a session. Those based on the stimulation plan of Sect. 3 are highlighted in blue. For instance, the points acquired in a session's game trigger updates to the accuracy ratio of the learner. The update to the omission rate of the session is correlated to whether a session's game is skipped, or to the learner's resolution time for the game with respect to the allowed maximum resolution time in the session. In turn, the updates to the accuracy rate and the omission rate can trigger updates to the RC level of the learner at the conclusion of the session.

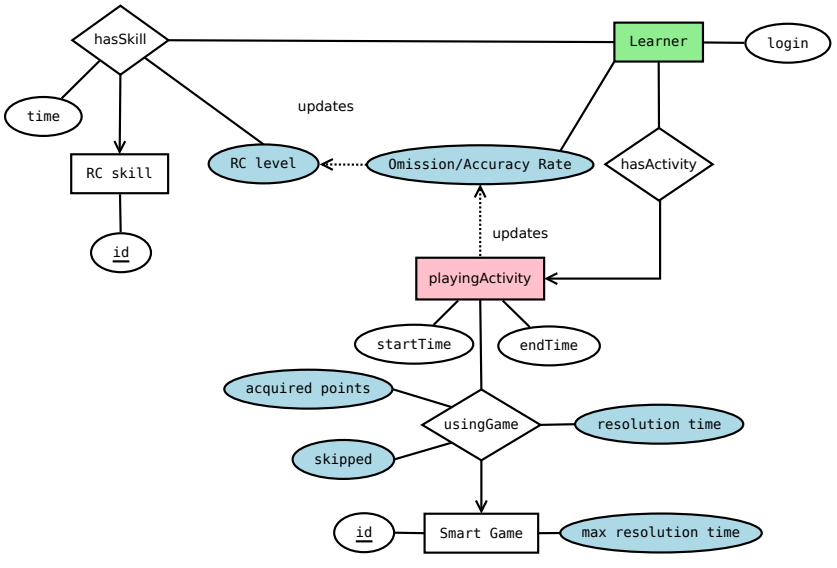

Fig. 3 The learner profile's update in a session

5 Conclusions

This paper described the adaptive model of the TERENCE system, and its EBD. The first phase of the design process, conducted by experts of the TERENCE con-

sortium, focused on the analysis of the context of use and user requirements. In particular, this process allowed us to informally specify the stimulation plan of the TERENCE system for its learners mainly through brainstorming meetings and contextual inquiries with therapists. The plan is rooted in daily clinical practice, based on evidence. The plan was then turned into the specification of the adaptation model, which thus follows the EBD. Both the plan and key ingredients of the model were explained in this paper. Future work will consider the adaptation of the feedback to the learner, as well as the adaptation rules for the other main users of the TERENCE system, namely, experts and educators.

Acknowledgments. The authors' work was supported by TERENCE project, funded by the EC through the FP7 for RTD, Strategic Objective ICT-2009.4.2, ICT, TEL. The contents of the paper reflects only the authors' view and the EC is not liable for it. The second author work was also funded through the CRESCO project, financed by the Province of Bozen-Bolzano.

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