Involving Learners and Domain Experts in the Analysis of the Context of Use for the TERENCE Games

Tania di Mascio[1], Rosella Gennari[2], and Pierpaolo Vittorini[3]

[1] DIEI – University of L'Aquila - Via G. Gronchi - 67100, L'Aquila, IT.
[2] CS Faculty, FUB - P.za Domenicani, 3 - 39100 Bolzano, IT.
[3] MISP – University of L'Aquila - P.le S. Tommasi, 1 - 67100 Coppito, L'Aquila, IT.

Abstract. TERENCE is an adaptive learning system for poor comprehenders, that is, children that demonstrate text comprehension difficulties, related to inference-making, despite proficiency in low-level cognitive skills like word reading. Its learning material will be stories and games for its stories.

There are several pencil-and-paper interventions by psychologists for improving inference-making skills, and educators have their own in their daily interaction with poor comprehenders. In order to analyse such interventions and transform them into the smart games of TERENCE, we adopt the user-centred design methodology. This means, first of all, analysing and specifying the context of use of the system via an ad-hoc approach, consisting of a preparatory preliminary study, followed by field studies.

The paper describes this approach and hence the main results relevant for the design of the TERENCE games.

1 Introduction

The TERENCE project [8] is a European project that aims at designing an adaptive learning system [7] for improving the reading skills of British and Italian poor comprehenders, namely, 7-11 year old children, hearing and deaf, that have difficulties in relating the meaning of sentences in a text, making inferences and detecting inconsistencies in what they read [12]. In this paper, such children are referred to as the TERENCE *learners*. Teachers (class and support teachers) and parents of such children are referred to as the TERENCE *educators*.

For designing and evaluating the TERENCE system, we adopt the user centred design (UCD) methodology [6]. The analysis of the context of use is a mandatory first step in UCD. In the TERENCE project, analysing the context of use also means: (1) analysing the assessment of poor reading comprehension of 7-11 year old children in Italy and the UK [3, 4], and hence the requirements of the TERENCE learners; (2) analysing typical reading comprehension interventions, then specifying which should be implemented as games in TERENCE, and how [5].

For conducting such an analysis, we followed an ad-hoc approach, described in Section 2: the analysis was divided into two main parts: a first part consisting of a preparatory study, a second part consisting of field studies. Such a division, demanded by the cross-disciplinary nature of the consortium and project, allowed us to properly set the goals and methodologies of the field studies. Section 3 briefly reports on such

studies, detailed in [9], though focusing on the results of the analyses that are useful for designing the smart games of TERENCE.

2 The Adopted Methodology

Generally speaking, the UCD methodology places the end user, user organisations and support teams at the centre of the design and evaluation processes. This means that the system's users are involved from the very beginning of the project, and can participate in the design and evaluation of the system. The iterative design of UCD revolves around the following main activities: (a) analysing and specifying the context of use; (b) specifying the user requirements; (c) producing design solutions; (d) evaluating designs against requirements.

At this stage of the project, TERENCE deals with analysing and specifying the context of use, which means analysing and specifying the following in relation to the TERENCE users:

1. characteristics of the users, that is, of the TERENCE learners and educators.
2. users' tasks, that is, the users activities in relation to reading comprehension.
3. environments, divided into: the physical environment in which educators and learners read, and the satisfaction associated with it (e.g., school, house); the instructional environment in which educators and learners do their activities; devices (e.g., software) for such activities.

The TERENCE context of use is so articulated that its analysis required first a comprehensive and long preparatory study, and then field studies. The preparatory study involved ICT researchers, cognitive and educational psychologists of the consortium, and educational stake-holders. The two field studies, one in Italy and the other in the UK, involved the experimenters, learners as users of the system, teachers and parents as users of the system, and teachers as domain experts. The adopted methods were:

- for the preparatory studies: brainstorming meetings, the study of the state of the art, and the study of the bureaucratic documentation;
- for the field studies: diaries, observations and contextual inquiries.

Field studies are standard in the UCD context, whereas preparatory studies are a need of the TERENCE project. In fact, the latter studies were supposed (and demonstrated to be) necessary for building the knowledge base of the consortium team, which is highly cross-disciplinary, and hence for gathering information relevant for the field studies, like the characteristics of the TERENCE learners known in the literature and the different administrative, legal and ethical issues in UK and Italy.

The preparatory studies dealt with the learners' characteristics, the reading comprehension task, and the organisational environment. The field studies dealt with the learners' and the educators characteristics, the reading comprehension task, and the physical environment.

3 Results of the Studies

As mentioned in the introduction, the TERENCE system will be developed as an adaptive learning system. According to [7], an adaptive learning system is so composed:

1. it has models describing the learner's relevant information (student model), the repository of the material (domain model), the description of the user hardware and software capabilities (environment model), the inferential rules that, given the previous models, provide the actual adaptation (adaptation model), and
2. it has engines that actually personalise the learning process by selecting the adequate material for the adequate learner by means of its conceptual model and properly assessed metrics (adaptation engine).

In particular, the domain model consists of a story sub-model, and a game sub-model. This section aims at supporting the definition of the game sub-model, and of the related metrics. More precisely, hereby we recap the results of the studies, focusing of the analyses that are useful for designing the TERENCE games. We first summarise the learners' requirements in Subsection 3.1, then report on the tasks as in Subsection 3.2.

3.1 Specification of the User Requirements with Psycholinguists

The learners of TERENCE are divided into two classes: hearing poor comprehenders and deaf poor comprehenders. Their reading comprehension skills were analysed in the preparatory studies with cognitive psychologists expert of deaf children or hearing poor comprehenders, and confirmed by the field studies.

The preparatory studies started with brainstorming meetings between the designers of the TERENCE system and the domain experts of the TERENCE consortium: cognitive psychologists and psycho-linguists. According to them, there is experimental evidence that interventions centred around inference-making skills can improve the reading comprehension of poor comprehenders, e.g., see [13, 12, 11]. Inference-making interventions could be further classified as follows, e.g., see [2]:

1. *Lexical inference* interventions are usually questions whose answers are, literally, in the text;
2. *Propositional inference* requires performing logical inferences, and are of three types:
   (a) Logic information inferences, i.e., ask the reader to determine the main features of an event, namely, the involved characters and their attributes, the time and location of an event. In other words, inferring logical information means answering "who", "what", "where", and "when" questions;
   (b) Logic explanatory inferences means providing the intentions (goals) of the characters, as well as the causes and consequences of events, and conditions that enables the events to occur. Inferring explanatory information means answering questions of the form "why" and "how";
3. *Pragmatic inferences* relate to the reader's store of prior knowledge, hence the related questions are considered to be scriptural implicit.

The meetings also led to a preliminary specification of the characteristics of the TERENCE learners in November 2010, which were then assessed and refined through the field studies in January 2011. In detail, the specifications of the learners' reading skills were organised in tabular format: a table for hearing poor comprehenders; another table for deaf poor comprehenders. See [9]. The skills in the tables were divided into four coarse-grained levels of comprehension:

- sub-lexical level, e.g., knowledge of morphology,
- word level, e.g., knowledge of abstract words,
- sentence level, e.g., reconstructing a sentence in a grammatically correct order,
- entire-text level, e.g., detection of inconsistencies in the entire text,

starting from the easiest to the most complex skill to gain. Each of the above four levels was sub-divided into finer-grained levels of comprehension, by reporting whether the are evidences of difficulties or not.

The novel division adopted in the tables aims at resolving some of the ambiguities of the inference-making classification mentioned above, whose practical usage for the interventions is quite difficult. For instance, the three inferential concepts/skills and sub-concepts (i.e. logic information inferences, logic explanatory inferences, and pragmatic inferences) are not clearly separable in the opinion of the domain experts gathered during brainstorming meetings and field studies: more than one of them can be jointly activated by a learner which makes it difficult to classify interventions as "only" information, explanatory, pragmatical. Therefore they are all considered as inference-making interventions. However, an inference-making intervention can be classified according to the type of question (why, how, when, where, who) it triggers, e.g., temporal, spatial, causal.

3.2 Specification of the Interventions with Education Experts

Tasks in this phase of the TERENCE project are the activities done by the educators while and after reading stories with their learners. The brainstorming meetings with educational psychologists and stake-holders, plus the study of the state of the art outlined above, as well as the analyses of the field studies reported in [9], suggested that the most common strategies for teaching reading comprehension by educators, and particularly in the Italian context, are based on an analysis of stories that closely follows the story model reported in [10].

The model recaps and organises the salient interventions for the explanation of a story that educators propose to their learners. Initially, educators read aloud the story with their learners. Then they focus on the unknown vocabulary that the learners may have encountered: they let their learners think about the hypothetical meaning, thus give the precise definitions, and finally read further sentences containing the new vocabulary. Second, they ask the learners to divide the story into macro-sequence, that is, they analyse the story grammar (setting, initiating episode, change episode, resolving episode, final episode). Then, they start a set of activities focusing on temporal, causal, spatial relations between events and the relations between the actors of the story, besides analysing the main characteristics of the story's actors, e.g., their behaviour or their physical attributes.

4 The Preliminary Design of the TERENCE Games

Hereby, we design the TERENCE games by revisiting the reading comprehension tasks in light of the user requirements resulting from the aforementioned studies. We explain the videogame format of the TERENCE system for its leaners, and its rationale. Then we focus on the different types of envisioned games, and outline diverse difficulty metrics for them, all resulting from the aforementioned studies and to be further evaluated with ad-hoc studies.

4.1 Stimulation Environment

In [1], Chatfield sums up seven ways in which games enhance learning: tangible objects, like avatars, for measuring one's progress; the co-existence of multiple long and short-term goals; rewards; rapid, frequent and clear feedback; uncertainty as a surprise element; windows of enhanced attention; the involvement of other people or characters for collaborative learning.

Whereas the latter can be problematic for the TERENCE learners according to our field studies, all the others emerged as desiderata for the TERENCE games according to the studies. In particular, the videogame format seems very appealing for poor comprehenders, in UK and Italy, hearing and deaf; sometimes, these children read a book if they have seen a movie of it. Thereby, in TERENCE, the stimulation of a learner takes place in a virtual environment. The learners chooses a story that takes place along a spatial map with a certain scenario, and a companion avatar. Each story is divided into several short chapters, and each chapter is visualised in a specific location on the map. Each chapter has its own set of games.

The progress of the learner from the read chapter to other chapters depends on his/her resolution of the chapter's games. What other chapters the learner can move forward is decided upon by the adaptive engine with the possible assistance of the educator, i.e., the difficulty level of the forthcoming chapters is decided upon by the engine and possibly the educator. The new chapters the learner can choose among are shown along different paths in the map. The learner can choose which new chapter to read by moving his/her avatar on it in the map.

The progress in the story is visually displayed not only by means of the path that the avatar has gone through, but also by the growth of the avatar itself. Moreover, the learner receives constant and evident feedback on his/her progress in each game.

Games of different classes and difficulty are alternated so as to keep the learner motivated in learning so as to grant him/her time to relax after a difficult game as well as to avoid exceeding frustration and thus keep him/her motivated in playing for learning.

4.2 Classes of Games per Chapter

By matching the interventions by education experts of Subsection 3.1 to the the requirements of the TERENCE learners outlined in Subsection 3.2, we have features of stories that the games of TERENCE must focus on. The three main ones are as follows.

1. Difficult linguistic expressions. The main difficulties of the TERENCE learners are related to abstract, infrequent or non-familiar words, besides attributes of characters,

idioms and, more generally, anaphoric expressions, whose difficulty seem to depend on the distance (measured in the number of intermediate words) from the resolving expression. Games concerning linguistic expressions should focus on such classes.

2. Narrative sequence. A story should be decomposed into its macro-sequence (see above), into its episodes and events. In particular, TERENCE should feature multiple-choice games concerning an episodes or an event, more precisely, its:

1. space of occurrence with attributes: internal, external, real, unreal;
2. characters;
3. relation to another via:
   - qualitative temporal relations: the relation can be conveyed via a connective (before, after, meanwhile etc.) or not; the relation can be between adjacent episodes or non-adjacent episodes (two are adjacent if they occur in the same sentence or in contiguous sentences; else they are not adjacent);
   - causal relations indicating whether an episode is a precondition or postcondition for the other; an analysis similar to that for temporal relation holds;
4. time of occurrence;
5. emotional appeal (calm, peace) that it or its sub-concepts (e.g., locations) evoke.

3. Actors. Each actor of a story has a number of characteristics that can be the object of multiple-choice games:

1. attributes in story/episode/event: moral (bad, good, etc.); physical (tall, small, etc.);
2. relations to other characters in story/event/episode, e.g., opponent, friend, other;
3. role in story, e.g., protagonist, antagonist, other;
4. role in event/episode, e.g., subject, object, other.

4.3   Difficulty Metrics

Possible metrics for measuring the difficulty of a game are given by the number of classes the game falls in. For instance, consider a game concerning an episode, asking when that episode happens. In this case, the game falls within the narrative sequence class above. If the game also requires resolving an anaphoric expression within the same sentence then the difficulty level of the game increases. If the anaphoric expression and its resolvent are in two different sentences, the difficulty of the game increases again.

Even if two questions fall within the same class, they may be of different difficulty. For instance, the number of episodes to be temporally correlated is another difficulty metric. The more episodes one has to reorder, the more difficult the game may become.

It will be the role of the adaptive engine of TERENCE to select the proper difficulty level, depending on the learner's profile[1].

---

[1] We also remark that a stimulation protocol must include sequences of games, that breaks up into easy games and difficult ones, so to give children the possibility to relax after a challenge.

5 Conclusions

The paper outlined the preparatory and field studies of the context of use of the TERENCE project and presented a preliminary design of the games resulting from them. In particular, we highlighted the ad-hoc methodological approach for the analysis. The design of the games focuses on the stimulation environment. Finally, we focus on the different types of envisioned games, and outline diverse difficulty metrics for them, all resulting from the aforementioned studies and to be further evaluated with ad-hoc studies.

References

1. T. Chatfield. 7 Ways Games Reward the Brain. TED Global 2010.
2. I. Chikalanga. A Suggested Taxonomy of Inferences for the Reading Teacher. *Reading in a Foreign Language*, 8, 1992.
3. C. Cornoldi and G. Colpo. *Prove di lettura MT*. Giunti, 1998.
4. GL Assessment. *YARC The York Assessment of Reading for Comprehension*. 2011.
5. S. R. Hedberg. Executive insight: Smart games: Beyond the deep blue horizon. *IEEE Expert*, 12(4):15–18, 1997.
6. International Standards for Business, Government and Society. *ISO 9241-210:2010 – Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems*, 2010.
7. J. Santos, L. Anido, M. Llamas, L. Álvarez, and F. Mikic. *Computational Science*, chapter Applying Computational Science Techniques to Support Adaptive Learning, pages 1079–1087. Lecture Notes in Computer Science 2658. 2003.
8. TERENCE Consortium. *TERENCE Description of Work*, 2010.
9. TERENCE Consortium. *D1.1 – State of the art of methods for user analysis and description of context of use*, 2011.
10. A. Valeriani. *Ermeneutica retorica ed estetica nell'insegnamento verso l'oriente del testo*. Andromeda, 1986.
11. A. Whatmuff and J. Puttick. Developing and evaluating inference awareness training in a local authority. In *Paper presented at an ESRC-funded seminar: Reading Comprehension: Linking Theory and Practice. Seminar 4: "Intervention and Assessment"*, 2008.
12. N. Yuill and T. Joscelyne. Effect of organizational cues and strategies on good and poor comprehenders' story understanding. *Journal of Educational Psychology*, 80(2):152–158, 1988.
13. N. Yuill and J. Oakhill. Effects of inference awareness training on poor reading comprehension. *Applied Cognitive Psychology*, 2(33), 1988.