READING AS PLAYING: A NEW TUTORING MULTIMEDIA TOOL FOR CHILDREN WITH TEXT COMPREHENSION PROBLEMS

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ABSTRACT

Nowadays, several children have deep text comprehension problems, despite well developed low-level reading skills. We are working on a tutoring multimedia tool aiming at implementing a series of reading intervention for such children through smart game. This paper reports on the main choices of our tool, and results of our evaluations.

KEYWORDS

Supporting user populations with Physical Disabilities. Graphical Interfaces. Usability.

1. INTRODUCTION

Developing the capabilities of children to comprehend written texts is key to their development as young adults. Text comprehension skills and strategies develop enormously from the age of 7-8 until the age of 11, when children develop as independent readers. Nowadays, more and more children in that age range demonstrate difficulties in deep text comprehension, despite well-developed low-level cognitive skills like vocabulary knowledge. Several studies experimentally demonstrate that these children with deep text comprehension problems fail to master the following reasoning skills in processing written stories, skills that are causally implicated in the development of deep text comprehension: (s1) coherent use of cohesive devices such as temporal connectives, (s2) inference-making from different or distant parts of a text, integrating them coherently, and (s3) detection of inconsistencies in texts.

For instance, see (Cain and Oakhill, 1999) for the case of poor comprehenders, circa 10% of the 8-10 olds without physical disabilities, and see (Marschark et al., 2009) for the case of deaf children. In particular, experiments show that inference-making questions centred around ((s1), (s2), and (s3)), together with adequate visual aids, are pedagogically effective in fostering deep comprehension of stories, e.g., see (National Reading Panel, 2000).

We are working on a tutoring multimedia tool for hearing poor comprehenders and deaf children, aged 8-10, that fail to master the above reasoning skills. Stories, adapted to the specific requirements of these children, constitute the reading material of our tool (currently, in Italian). Like Intelligent Tutoring Systems (ITSs), our tool aims at producing learning gains. However, students often dislike interacting with ITSs. According to several authors, e.g., (McNamarra et al., *in press*), a potential remedy lies in games. Nowadays children are used to multimedia environments (albeit not all are equally skilled in them), and approach learning with different expectations than children of 20 years ago. This is particularly the case of our tool's users: according to the experts we interviewed, our end users like playing videogames that motivates them more than print reading. Our tool, therefore, foresees interactive games for engaging children in reading,

deeply, stories. The games have questions centered around reasoning skills like (s1), (s2), and (s3) above for fostering the texts' deep comprehension. The currently games invite readers to reason on the main events of a story, and correlate them by means of temporal cohesive devices like "before", "while" or "after". In this manner, the games will help readers in constructing their mental model of the flow of the story's events.

Based on the seminal work of (Pavio, 1991), numerous studies already showed significant comprehension gains when people can appropriately visualize while reading, as reported in (Johnson and Glenberg, 2005).

Our tool aims to be visual as for: the global interface, the story's main events, and the games. This paper reports on the main choices of our learning multimedia tool, and results of our evaluations.

2. THE USER INTERFACE

The Graphical User Interface (GUI) of our tool is designed following the focus+context method and developed in Adobe Flash 4. The GUI aims at implementing the tool's main functionalities: reading the stories, playing the games, and analyzing the difficult words of the story. The user is invited to read a story; after reading and possibly analyzing the story's difficult words, the user can choose to play the tool's interactive smart games that pose different types of questions for reasoning over the read story.

As our main goal is enjoying the stories' reading and playing experience, the GUI design emphasizes the role of the stories' illustrations whereas all the other design elements of the GUI (e.g., help) are sober and neutral. The use of metaphors is very limited and there is no use of anthropomorphic elements other than the characters contained within the illustrations to the stories. In this manner, we aim at enhancing the visual strength of the illustrations for the stories and games. Following the same principle, a textual help guide was preferred over an agent in order to avoid any possible visual clash or competition with the reading or playing activities. Moreover, children can get as quickly bored with artificial characters as adults do, and tend to ignore their instructions (Preece, 2002), whereas this does not happen as quickly with textual instructions. Sound is not used, since also profound deaf children are among the end users of our tool.

Since the cognitive processes in young children rely on a direct experience of reality, and more specifically on a complete sensory and motor perception of space and objects (Bernardinis et al., 1994) the GUI of our tool aims at offering a perceivable environment in its entirety through a reduced number of interaction modalities: the *exploring*, the *story reading*, the *word analyzing* and the *game playing* modalities.

Figure 1. Page Structure: the text (the context) in the left panel is always displayed, the right panel contains the focus (illustrations, words, and videogames) that changes in relation to the modality chosen by the user.

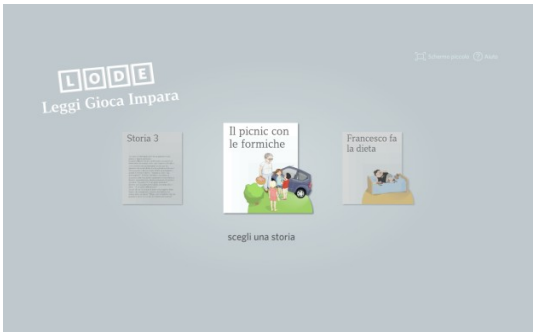
The tool's modalities are realized in the *entrance page*, the *story page*, *the word page*, and the *game page*. The last three pages are in turn composed of two panels: the left panel and the right panel. The general structure of the page is shown in Figure 1. The left panel of the story, the word, and the game pages is the *text* panel, implementing the reading modality, as that figures shows. The right panels of those pages have different purposes and contents that depend on the page: the *illustration* for the story page, the *vocabulary* for the word page, and the *videogames* for the game page. So, the right panel of the word page implements the *word analyzing* modality, and the right panel of the game page implements the *game playing* modality. All pages implement the *exploring* modality. Such choices realize the focus+context design of the GUI. Except for the entrance page, the other pages always display the context (that is the story text), and the changes of focus in relation to the modality. Modalities, pages and panels are described at length in what follows.

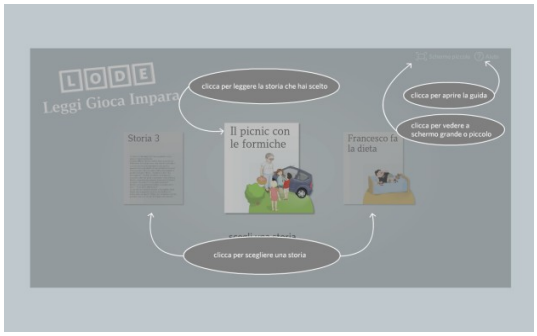
2.1 The Exploring Modality

The exploring modality, present in all pages, serves to: (1) browse among the stories; (2) browse among the story' words of the vocabulary; (3) browse among the games; (4) browse the help; (5) discover the two types of panels; (6) navigate the other three modalities: the story, the vocabulary and the game modalities.

In the case of 1, 2, and 3, the user can browse stories, words and games fading in/fading out their respective representations: iconic stories titles in the entrance page (see Figure 2), story' words in the right panel of the word page (that is the vocabulary panel, see Subsection 3.3), and iconic names of games in the right panel of the game page (that is the videogame panel, see Subsection 3.4). Once the user chooses a story, s/he can choose another one just closing the first and returning to the entrance page; operatively, s/he clicks on the “chiudi” (close) link positioned in the top left part of the pages, e.g., see Figures 4 and 5.

Figures 2 in the left part. Entrance Page: fading in/fading out stories. Figure 3 in the right part. Entrance Page: the Help.





The help is designed as a transparent layer that displays on top of the applications and is accessible at any time with one click on the “aiuto” (help) link positioned in the top right part of the GUI pages. The help presents balloon-like instructions written in a conversational, children-friendly style, e.g., see Figure 3. More in general, each page has its own help that, for coherency, is kept as a simple textual guide through all modalities. It is sufficient to click on any part of the GUI in order to exit the help.

The default choice of the screen is the small screen; to go in the full screen mode, the user can easily click on the “schermo grande” (big screen) link; otherwise, if the user is in the full screen mode, the GUI returns in the small screen mode by clicking on the “schermo piccolo” (small screen) link.

In order to explore the story, word and game modalities, the users have at their disposal corresponding navigation links, labeled “leggi” (read), “parole” (words), and “gioca” (play). They are displayed in a top bar as boxes, with graphical representations. The user accesses a modality by clicking on the link in the corresponding box, e.g., the user accesses the game modality by clicking on the “gioca” (play) link. This box remains of small size while the user remains in the chosen modality. See Figures 4 and 5.

Figures 4 in the left part. Word Page: the closed box of the navigation links is relative to the Word modality. Figure 5 in the right part. Game Page: the closed box of the navigation links is relative to the Game modality.

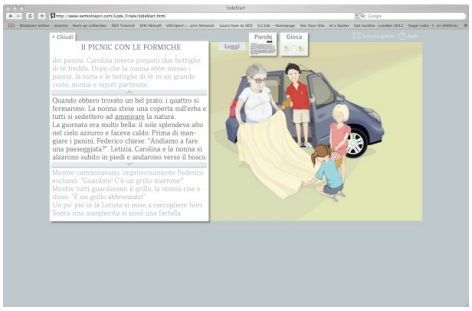
2.2 The Story Reading Modality

These modality presents a set of stories. Once the user chooses a story in the entrance page, the story is displayed in the story page. The left panel of the story page is the text panel: it shows the text of the story. The right panel of the page is the illustration panel: it shows the illustrations of the chosen story. In the left panel, the text is chunked into paragraphs, each corresponding to an episode of the story. Each episode has its own illustration. This is placed on a spatial map shown in the illustration panel to the right (Figures 6 and 7). The episode in the center of the text panel is displayed in a frame delimited by two arrows, a top and a bottom gray arrows. The frame works as a sort of lens for highlighting the episode. The user moves from the highlighted episode to the adjacent episodes with these scrolling. Correspondingly, the right panel moves through the map and zooms in on the illustration that shows the currently highlighted textual episode. The episode-stream in the text panel is synchronized to the animation in the illustration panel. Nevertheless it is the user who determines the pace of streaming accordingly to his/her needs in reading in the text panel.

2.2.1 The Text Panel

Textual navigation in the left text panel is constrained and over simplified primarily for avoiding any potential cognitive overload other than that due to text reading (Salmerón and García, *in press*). In particular, each story is displayed in one single page for allowing the user to gain an immediate global overview of the story's length and structure, unlike what would happen with a text displayed through several pages as in LODE (Gennari and Mich, 2007). Adjacent episodes are displayed next to the highlighted episode for simplifying the memorization of the ordering of events in the text, and hence easing the user's orientation within the text. Such a persistence of context allows the user to move back and forth between difficult episodes several times, viewing them always embedded in their surrounding context.

Figures 6 in the left part. The Story Page: the second episode in the text panel and its own illustration in the illustration panel. Figure 7 in the right part. The Story Page: the fifth episode in the text panel and its own illustration in the illustration panel.



2.2.2 The Illustration Panel

According to our expert-based evaluations (see Section 4 below), the illustration of a textual episode should not become a shortcut for the comprehension of the text: story-reconstruction through the viewing of the images has to be made impossible so that the user is compelled to read the text. Therefore, illustrations do not present any visual clue concerning the temporal flow of the stories on purpose. At the same time, the visual component of the application must be appealing and comply with the standard of printed books for children, where illustrations function as memory-reinforcement and attention-catalysts. Then, the illustration of an episode characterizes the actors and the spatial locations of the episode's main events (Figures 6 and 7).

The movements from one illustration to the other are rendered as camera movements over the spatial map through sliding, zooming in, and zooming out effects between freeze frames of single locations on the main scene. The global view over the map allows for the direct perception of the whole narration; the narrative space is thus directly perceivable as a physical space where the illustrated episodes are physically located. This creates a perceivable correspondence between the textual episode and its illustration, between the user's

movement through the text and the camera movements in the map. Notice that animation is used exclusively to display camera movements. As such, the animation has the precise function of attracting the user towards the story's episodes, their actors, and their spatial locations. Such a spare use of animation effects has to be ascribed to their ambivalent potential, both in attracting attention, but also in unwanted power to distract the user from the priority action, which is reading. Please note that the illustration in the navigation link box "leggi" (read) is coherent with the episode's illustration in the right panel.

2.3 The Word Analyzing Modality

This modality, implemented by the word page, presents the meaning in Italian and in LIS (Italian Sign Language) of a set of all the potentially difficult words of the stories for the intended end users. Once the user clicks on the navigation link "parole" (words, see Section 3.1), or on the highlighted word in the text panel, the word page appears. The left text panel of the word page shows is the text panel; the right panel is the vocabulary panel and shows the meaning of the clicked difficult word.

2.3.1 The Vocabulary Panel

This panel presents, in the low part, the textual meaning of the highlighted word, and, in the top part, the LIS video translation of the clicked word with explanations and usage examples (see Figure 4). As in the case of the illustration panel, also in this case, the contents of this panel changes coherently with the choices made in the text panel. There is a complete simultaneity in following the stream in the text panel through its difficult words and their translation in the vocabulary panel.

2.4 The Game Playing Modality

The game playing modality of the game page presents three types of question-games in the currently implemented version. The implemented questions address specific features of events (e.g., who bakes the cake?, see Figure 8), and causal-temporal relations between events (e.g., do the ants eat the picnic before grandma returns from her stroll?). They are based on comprehension interventions centered around inference-making in order to improve the text comprehension skills of the intended end users. See Section 1.

Once the user clicks on the navigation link "gioca" (play, see Section 3.1), the game page appears. Again, the left panel of the game page is the text panel, consistently with the other modalities. The right one is the videogame panel. The narration is kept available all the time to be read and got over again during game playing. In fact, children solve logical operations more easily on material they can perceive directly through the senses; as soon as they have to operate on an abstract level their failure rate tends to increase.

2.4.1 The Videogame Panel

The videogame panel, to the right, proposes three types of games concerning the read story. Each type is rendered with its own iconic representation.

The games are in a videogame format that is both familiar and attractive to its users (see Figure 8). The user plays and accumulates points according to his/her answers to the game-question. The scores are always available as feedback, so that the users can monitor their text comprehension and are also encouraged to gain more points (see Figure 9). The written story is always available in the left panel and can be scrolled with the scrolling arrows while playing. In this manner, our user can always reread a passage of the written text, operate logically on the text, and answer a question in the playing area in the right panel.

Figures 8 in the left part. The Game Page: the games questions. Figure 9 in the right part. The Game Page: the final score of the game

3. EVALUATION

As recommended in the user-centered design methodology (UCDM) (Norman and Draper, 1986) the conceptual design of the tool developed through evolutionary prototyping from the beginning throughout the whole project. The prototyping phase lasted circa twelve months (June 09–August 10) and comprised low-fidelity (paper sketches, storyboards) and high fidelity versions built in adobe flash. The version presented here is the latest flash-prototype, developed in September 2010 after going through several iteration cycles and evaluations. The evaluations concerning the usability of the tool were performed using expert-based methods (the cognitive walkthrough method (Wharton et al., 1994)) and user-based methods (observational evaluation and verbal protocol (Hartson et al., 2001)). Hereby we recap the results of the main evaluations.

3.1 Expert-based Evaluations

Following the cognitive walkthrough method, the designer conducted separate evaluation sessions about specific issues with experts concerning: the illustrations of the stories, and their function with two experts of children's literature; the overall design choices (e.g., typography) with an expert of multi-media communication and psychologists expert of our end-users; the usability of the tool with an expert of usability.

The expert-based evaluations with the experts of our end-users made us choose not to illustrate temporal features of the stories in the right panel of the story modality, as explained above. The subsequent evaluations with the experts of story illustrations were all positive concerning the realized illustrations. The evaluations with usability experts served to resolve predictable usability problems.

3.2 User-based Evaluation

These evaluation aimed at detecting further usability problems and assessing the user satisfaction. In particular: *Assessment Goals*: Assessment of – G1: text usability (color, font, link); ‚G2: links quality; G3: the help interaction; G6: browsing among modalities; G6: games interaction; *Coherency Goal*– G5: coherency between the illustrated episode and the textual episode; *Satisfaction Goals* – Satisfaction in – G7: playing games; G8: reading stories; G9: reading word' definitions.

The sessions of this evaluation were conducted based on a classical HCI user based schema, e.g., see (DiMascio et al., 2005). The methods are direct observational evaluation methods and verbal protocols.

3.2.1 User Analysis

Our experiment participants were 3 children aged 8–10 year old. *User A*: female, 10 year old; hearing; medium degree of text comprehension; low attitude to reading book; high attitude to see cartoons; low attitude to playing videogames. *User B*: male, 8 year old; hearing; low degree of text comprehension; low attitude to reading book; high attitude to watching cartoons; high attitude to playing videogames.

User C: female, 9 year old; hearing; medium degree of text comprehension; medium attitude to reading

book; high attitude to watching cartoons; medium attitude to playing videogames.

3.2.2 Experiment Design

In order to better observe users, we decide to make one session per users. Each session is divided into four phases, one per modality: Phase (1), exploring modality, addressing goals G3 and G6; Phase (2), the text reading modality, addressing goals G1, G4, G5 and G8; Phase (3), the word analyzing modality, addressing G9; Phase (4), the playing game modality, addressing goals G4, G6, and G7. For each phase we defined different tasks, listed as follows. Note that Tij is the task i of phase j.

Phase 1: T1,1: choose the "Francesco e la Dieta" story; T1,2: choose the "il picnic con le formiche" story; T1,3: ask for help; T1,4: close the help; T1,5: go to the game modality; T1,6: go to the vocabulary modality; T1,7: read another story; T1,8: quit the system. *Phase 2*: T2,1: read the story; T2,2: read the third episode. *Phase 3*: T3,1: read the definition of "furbo" (cunning) word; T3,2: see the LIS video of the "furbo" word. *Phase 4*: T4,1: play game "Salva i panini" (Save sandwiches); T4,2: play game "Calcio" (Football); T4,3: once the game ends, choose another game.

3.2.3 User Teaching

Before performing the experiment, the evaluator met the children's mothers. The evaluator discussed the organization of the experiment (e.g., meeting time, sequence and nature of tasks), and their respective roles in the experiment; e.g., mothers were asked not to support their child in any of the phases of the experiment.

3.2.4 Experiment Execution

We conducted the experimental sessions during the period of August 2010, in different dates (Users A,B,C on the 8th 10th, 18th of August, respectively). The location was the user's houses. The evaluator chose to start with the observational evaluation methods. At the end of each phase the evaluator asked the children questions about their mistakes, and indirect questions concerning their satisfaction, e.g., "would you like to play again this game or not?". In the following, we summarize the order of tasks per phase and per session user and the time spent for each session:
User A – Phases 1, 2, 3, 4 – Tasks T1,1; T1,3; T1,4; T1,5; T1,7; T2,1; T2,2; T3,1; T3,2; T4,1 – Time:1h.
User B – Phases 1, 2, 3, 4 – Tasks T1,2; T1,3; T1,4; T1,6; T1,5; T1,8; T2,2; T2,1; T3,2; T4,2 – Time: 30m.
User C – Phases 1, 2, 4, 3 – Tasks T1,2; T1,3; T1,4; T1,7; T1,8; T2,1; T2,2; T3,2; T3,1; T4,2 – Time: 1h.

3.2.5 Results Analysis

For space limitations, this section only gives the most significant results for the design of the GUI. These results are presented phase per phase.

Phase 1 – 1a) Tasks T1,1,2,8 – When the users interact with the entrance page, all of them easily choose their story and two of them positively comment on the illustrations. All users easily quit from the system. 1b) Tasks T1,3,4 – The Help is easily opened by all, but two of them (Users A and C) ask the evaluators on how to exit. 1c) Tasks T1,5,6 – Once the users are in the story reading modality, all of them can easily change to another modality. 1d) Task 1,7 – One of the users (User b) clicked on "chiudi" (close) to change the story. Others click on "leggi" (read), asking the evaluator why the system does not work as they would expect it.

Phase 2 – 2a) Tasks T2,1,2 – All users complete the tasks, but, when a user can preliminary read the third episode (T2,1) and then all the story (T1,1), he/she asks the evaluator about the location of the third episode. When the order of the tasks is T2,1 and then T2,2, all the users correctly use the scrollable arrows.

Phase 3 – 3a) Tasks T3,1,2 – All users easily complete the tasks, but none of them understand that an underlined word is to be explained in the word analyzing modality.

Phase 4 – 4a) Tasks T4,1,2 – All users easily choose the games and just one of them (User A) asks the evaluator which games to play (Which, When or Where), the others independently choose any of the games. 4b) Task 4,3 – Not all users complete this task. All of them ask about the button to click for playing again.

3.5 Short Discussion

Specific usability issues resulted from the described user based evaluation. For instance, the GUI of our tool needs a more prominent and explicit link to exit from the help. The typography of the text needs improvement, e.g., larger fonts; in particular we will evaluate other types of scrolling arrows, more evident than the evaluated ones. Moreover we should also more strongly highlight the word of the vocabulary in the

left text panel and the game exit needs to be more evident.

4. CONCLUSIONS

This paper presented and motivated the choices of our tutoring multimedia tool for 8-10 olds with deep text comprehension problems. The tool has illustrated stories and games for reasoning about specific features of its stories. Its games render typical reading interventions for our users in a playful format using the illustrations of the stories. More precisely, the games are in videogame format, which is appealing for our end users. Expert based evaluations were crucial for assessing the best type and role of illustrations for stories, and for choosing the videogame format for the tool's games. The user based evaluations, serving to detect and resolve usability problems, assess the satisfaction of our end users.

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