Faculty of Computer Science, Free University of Bozen-Bolzano
Via della Mostra 4, 39100 Bolzano, Italy
Tel: +39 04710 16000, fax: +39 04710 16009, http://www.inf.unibz.it/krdb/

KRDB Research Centre Technical Report:

Before, While and After with LODE and Hearing Novice Readers

B. Arfé[1], R. Gennari[2], O. Mich[2]

Affiliations	[1] Faculty of Education, U. of Verona
	[2] KRDB, Faculty of Computer Science, Free U. of Bozen-Bolzano
Corresponding author	R. Gennari gennari@inf.unibz.it
Keywords	HCI, evaluation, CP, constraint, intelligent user interface, deaf, children, text comprehension, novice readers
Number	KRDB09-1
Date	30-Jan-2009
URL	http://www.inf.unibz.it/krdb/

Abstract

LODE is a web tool for children who are novice readers, in particular deaf children; it proposes written stories and exercises for reasoning, globally, on the stories. In this report, first, we motivate the rationale of LODE, explain its reasoning exercises and their goals. The report briefly describes the design of the client-server architecture of LODE; the server employs a constraint programming system for creating and solving the LODE exercises in real time. Then we concentrate on the main matter of this report, namely, the evaluation of the latest prototype of LODE with hearing children who are novice readers. We conclude assessing the results of this evaluation, and explaining their use in the on-going evaluation with deaf children.

Contents

Chapter 1

Introduction

1.1 Background

Text comprehension enables a broad access to information and knowledge, thus being essential for both scholastic learning and professional achievements. In narrative, which is the most basic genre with which children interact, text comprehension depends on the readers' detection and deduction of logical dependencies, and on the construction of a global mental representation of causal and temporal relations between the narrated events [Bamberg, 1987,Trabasso and van den Broek, 1985]. In general, children develop adequate decoding skills in their first years of school; in shallow orthographies, such as Italian, text decoding is mastered early, by the age of 7 [Orsolini et al., ress]. Children become sensitive to the role of logical connectives in narratives and to the global meaning of texts between the ages of 7 and 8 [Thompson and Myers, 1985,van den Broek, 1997]. However, 7–8 olds are still *novice readers* as far as text comprehension is concerned; it is at this stage, when children start developing their reading comprehension strategies, that instructional intervention can be more effective.

The reading delay of deaf children is widely documented [Musselman, 2000,Traxler, 2000,Wauters et al., 2006]; due to a limited exposition to a verbal language in its spoken form in their first years of life, deaf people lack the primary, natural means of acquiring literacy in a verbal language, in particular, text comprehension [Musselman, 2000]. Their reading comprehension skills are reported to be usually equivalent to that of novice text comprehenders (novice readers onward), that is, children who have relatively adequate decoding skills, but still immature reading comprehension strategies, such as 7–8 olds [Allen, 1986,Furth, 1966,Traxler, 2000].

Deaf children often tend to reason on isolated concepts and not correlate concepts in written texts; this attitude may also depend on the kind of "literacy interventions addressed to deaf children" which tend to "focus on single sentences and the grammatical aspects of text production" [Arfé and Boscolo, 2006].

```
<EVENT class="E1">The small
eggs crack</EVENT>
<EVENT class="E2">Mammy duck,
worried, watches the big egg
</EVENT>, which is still closed...
<TLINK event="E1"
relatedToEvent="E2"
relType="before OR meets"/>
After some days,
also <EVENT class="E3">
the big egg cracks</EVENT>
<TLINK event="E2"
relatedToEvent="E3" relType="before"/>
```

Table 1.1: An excerpt of a tagged story in LODE.

1.2 The Rationale of the Report

A novel literacy e-tool for novice readers, like deaf children, should thus concentrate on neither the grammar nor isolated concepts, but reasoning, globally, on a narrative by correlating its events. In particular, “the research literature has shown that interactive storybook reading” supports “the deaf child’s emergent and early literacy development” [Schirmer and Williams, 2003]. This is the main educational goal of our e-tool: LODE narrates written stories and invite children to create simple stories; it then invites children to deduce consistent relations among events of the stories through apt exercises. A constraint programming system, embedded in LODE, is responsible for the consistency checking and the feedback to children.

In its current version LODE focuses on a specific type of deductive reasoning, namely, deductive temporal reasoning. Temporal dimension is a concept that children learn indirectly through narration. At the age of 5, normally developing children become able to make deductions about temporal relations, reasoning on sequences of events with “before” and “after” [McColgan and McCormack, 2008]. This ability seems to develop further from the age of 7 to that of 9 [Ge and Xuehong, 2002], when children become able to master the “while” relation. The LODE exercises use precisely the following temporal relations: “before”, “after”, “while”. We refer to them as the *LODE relations* henceforth.

This and the fact that 7–8 olds are novice readers (see Subsection 1.1 above) make an evaluation of LODE with 7–8 olds an important step, preliminary to an evaluation of the tool with deaf children. This report reports on the test of the latest prototype of LODE with hearing 7–8 olds, assessing the feasibility of its reasoning exercises with these children.

1.3 Outline of the Report

Firstly, the report outlines the general architecture of the current prototype of LODE, specifying the role of the constraint system in LODE; then it overviews the interface and exercises of LODE. With the preliminaries out of the way, we delve into the core of the report, namely, the design and evaluation of the latest prototype of the tool with hearing novice readers. On the basis of this evaluation and its assessment, we conclude outlining the goals of the ongoing evaluation with a group of deaf children.

Chapter 2

The Architecture

LODE features a web-based client-server architecture; see Figure 2.1. The server has a modular structure. The main modules are: 1) the e-stories' database, 2) the ECLiPSe constraint programming system [Apt and Wallace, 2006]. The stories' database of the current version of LODE contains temporally enriched versions of famous children's stories in XHTML format. Events and relations are temporally annotated in XHTML à la TimeML [TimeML, 2005]; the main difference is that we do not restrict the relations between a pair of events to the atomic ones [Allen, 1983]; this is needed for correctly rendering imprecise information, for instance, see "before or meets" in Table 1.1.

The annotations of events and relations of a story are automatically modelled as a constraint problem in the language of ECLiPSe, as exemplified in Tables 1.1 and 3.1. The server architecture, in general, and the constraint module, in particular, are detailed in [Gennari and Mich, 2007]; in the following, we only provide a short update on them and the necessary information for this report.

In essence, a *constraint (satisfaction) problem* is given by finitely many variables, $x_1, \ldots, x_n$, each ranging on a domain D_i of values, and a set of constraints, namely, relations of the form $C \subseteq D_1 \times \cdots \times D_n$. A tuple of domain values $a_1, \ldots, a_n$ for the variables $x_1, \ldots, x_n$ is a *solution* to the constraint problem if it belongs to all the constraints of the problem. We will say that a_i for x_i is *consistent* with the problem if a_i belongs to a solution of the problem.

In LODE, ECLiPSe solves a temporal constraint problem by deciding on the consistency of an Allen relation with the problem; for instance, with input the problem in Table 3.1, ECLiPSe will decide that "before" is consistent for E1E3, that is, "before" is a consistent relation between "the big eggs crack" (E1) and "the small egg cracks" (E3).

The client, a GUI, is an AJAX application compatible with most web browsers. It works as the interface between the LODE user and the remote server. The general features of the GUI are described in [Gennari and Mich, 2008a]; the following section gives the essentials on the GUI and describes the exercises employed in the latest prototype of LODE.

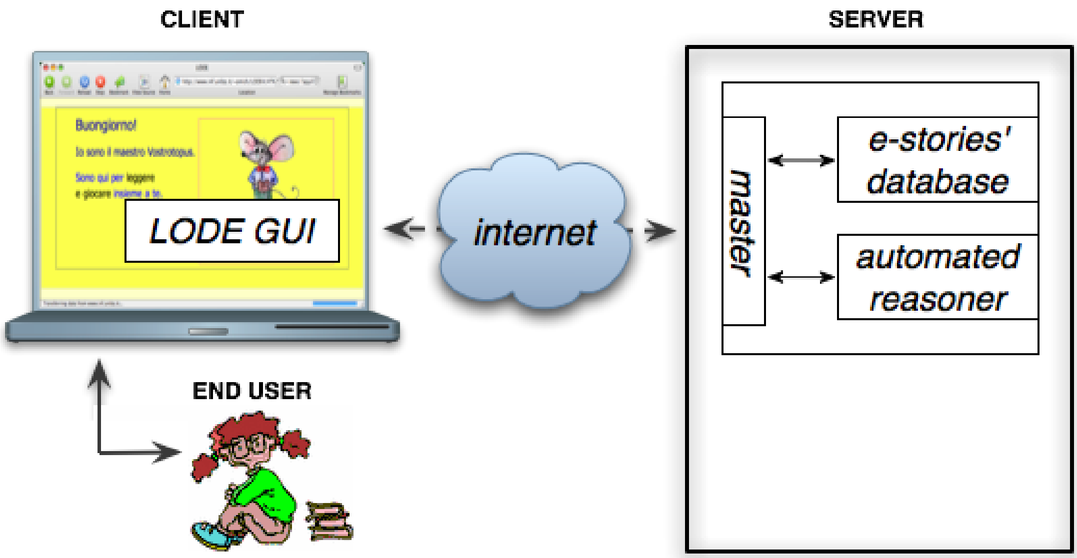

Figure 2.1: The LODE architecture.

Chapter 3

The Exercises

LODE narrates simplified versions of traditional children's stories, such as "The Ugly Duckling", so that the language is more suitable to novice readers, and deaf children in particular. The e-stories are also enriched with explicit temporal relations so as to concentrate the attention of the children on temporal events and relations. A story is divided into web pages as a storybook for young children. A demonstrator of the tool is available online [LODE, 2008].

Each story page only contains a written sentence and an image illustrating the relevant temporal event. Text in the story is centred and in big fonts, so as to attract the child's attention. After reading the story, the children can tackle the related exercises of LODE.

In the latest version of LODE, we have two main types of reasoning exercises demanding the constraint reasoner, namely, comprehension exercises and production exercises; they are separately described below.

The reasoning exercises use the LODE relations; see Subsection 1.2. According to [Schaeken et al., 2006], and in line with cognitive economy, people are often better with deductive tasks that admit solutions (a.k.a., models), and are happy with one plausible solution. The reasoning exercises of LODE are built on such findings, e.g., the exercises have only affirmative sentences, only relevant textual information, and at least one solution.

```
E1E2 &::  [before,meets],
E2E3 &::  [before],
allen_composition(E1E2, E2E3, E1E3)
```

Table 3.1: The constraint modelling in ECLiPSe for the annotations in Table 1.1.

3.1 Comprehension Exercises

In the comprehension exercises, the child needs to choose among the three LODE relations connecting a pair of events of the story; each event is described in words and by the related image in the story; the relations that the child has to choose among may be implicit in the story. The child should choose a relation that is consistent with the story; the constraint system provides the feedback deciding on the consistency of the chosen relation.

LODE proposes two visualisations of the relations: one is more textual (CTx), the other is more graphical (CGr).

(CTx). In the CTx exercises the two images representing the events are described in words, and connected by three choice boxes; each box proposes a written temporal relation. We took such a visualisation with choice boxes from young children's books. Note that it is only the text that conveys the relevant information for answering the exercises, thus the child has to interpret the text in order to answer. For an example, see Figure 3.1.

(CGr). In the CGr exercises a temporal relation between two events is also rendered by the spatial position of the relative images along the timeline; we propose such a spatial representation because several teachers for deaf children employ it. Note that it is not the text but this specific spatial representation of temporal relations that is conspicuous in the GUI, conveying information for tackling the exercises. For an example, see Figure 3.2.

3.2 Production Exercises

In the production exercises, LODE proposes a set of events that the children can relate with "before", "after" or "while" and so invent their e-stories. More precisely, children have at their disposal three events, grouped in two pairs, e.g., "Martina eats an apple" and "she plays a tennis match" is the first pair, "Martina plays a tennis match" and "she makes her homework" is the second pair; the children can temporally correlate the given pairs, to their liking. Given their choice, in the successive step they have to deduce a consistent temporal relation between the first event of the first pair and the second event of the second pair; in the example above, they should consistently correlate "Martina eats an apple" with "she makes her homework". Finally, the constraint system checks the consistency and gives the feedback. For an example, see Figure 3.3.report

Figure 3.1: A textual comprehension exercise; see also [LODE, 2008].

Figure 3.2: A graphical comprehension exercise; see also [LODE, 2008].

Figure 3.3: A production exercise.

Chapter 4

The Design and Evaluation Phases

The design and evaluation of LODE is split into three main phases, see also Table 4.1. We followed the user centred design (UCD) [Chadia et al., 2004], and lately adopted methodologies of the participatory design (PD) in the evaluations with children [Markopoulos et al., 2008].

First phase.

The first phase is since long completed; it helped us to specify the context of use and the user requirements. The users, considered in this phase, are two deaf children with their parents, and adults from different fields because LODE is designed as an interdisciplinary tool. The adult users of the test were: two teachers for deaf children; two logopaedists; a linguist, expert of deaf studies; a cognitive psychologist, expert of deaf studies; five usability and accessibility experts. In this manner, we could assess the user requirements and the context of use of LODE, outlined in Section 1. For more on the first phase, we refer the reader to [Gennari and Mich, 2008b].

Second phase.

The second phase is over as well. We run two evaluations with two groups of hearing children for a preliminary test of the usability of LODE. The production exercises, with more than three events per exercise, were then introduced and evaluated for the first time; after this second phase, they were simplified as described in Section 3 of this report.

Third phase.

The third phase measures the usability of the latest LODE prototype, and in particular the feasibility of its reasoning exercises. The following section reports on the test of the third phase with hearing 7–8 olds, that is, novice readers that should be able to reason with the LODE

Table 4.1: Evaluation of LODE.

	Phase 1	**Phase** 2	**Phase** 3
Users	teachers for deaf children and LIS interpreters; a logopaedist; a linguist, expert of deaf studies; a cognitive psychologist, expert of deaf studies; usability and accessibility experts; 2 deaf children	two sessions: the first with 14 hearing children, the second with 19 hearing children, all aged 8–13	31 hearing children, all aged 7–8; 7–9 deaf children, all aged 8–13
Evaluation goals	analysis of the context of use and the user requirements	interface and interaction, best age and emotional response	usability tests of LODE, in particular, the feasibility of the exercises
The LODE prototype	a first prototype, with the dictionary, comprehension exercises, (P1) and (P2) production exercises	a second prototype and a third prototype, implementing a number of the exercises	a mature prototype, implementing all the exercises with the constraint reasoner
Evaluation methods	interviews, heuristic evaluation, observational evaluation	observational evaluations	observational and controlled evaluations
Status	concluded	concluded	in progress

relations, as explained in Section 1. In the future, the results of this test with hearing novice readers will be compared to those of the on-going test with deaf children.

Chapter 5

The Evaluation with Hearing Novice Readers

5.1 Goals

The evaluation with hearing novice readers gives the following parameters: (a) the qualitative emotional response of children; (b) the time performance, that is, how long a child takes for reading the story and for completing the exercises; (c) the accuracy in answering the exercises.

Such parameters allow us to: (1) assess the feasibility and liking of the exercises; (2) compare the two visualisations of the temporal relations in the comprehension exercises.

5.2 Method

The test was run as a field experiment [Markopoulos et al., 2008]. It took place in the multimedia lab of the children's school; it was run with three groups of children, one group per day.

5.2.1 Participants

The test involved thirty-one children: seventeen girls and fifteen boys. Five children were 7-year old, the remaining children were all 8-year old. All children were at the start of the third class of an Italian primary school. They had had the same teachers during their primary-school years; hence they had received a similar literacy instruction at school.

5.2.2 Apparatus

For the evaluation of LODE we used fourteen PCs; one worked both as server and client, the other thirteen were connected to the server, running the latest version of ECLiPSe via a simple router. All the PCs displayed the GUI of LODE using Mozilla Firefox.

5.2.3 Procedure

Computer session.

Each child worked with LODE on his or her own computer. Before starting the computer session, a class teacher quickly informed the children that they only had to do what it was written on their display and follow the interface arrows. The children had to fill in an questionnaire concerning their computer literacy. Then they had to read the "The Ugly Ducking" story, and could do it more than once; however, they could tackle the exercises of LODE only after reading the entire story at least once. The log file of each child stored the following data: the time spent on the story, the time spent on each exercise, and the number of trials/clicks per exercise before resolving it correctly. During the session, the test administrator also observed the children and took notes about their questions and general behaviours.

The children could see the forward arrow and move to the subsequent exercise only after correctly resolving the current one. They had first six comprehension exercises, and then two production exercises; see Section 3 above.

When tackling the comprehension exercises, the children were divided in two groups: (1) the TG group, composed of fourteen children; (2) the GT group, composed of seventeen children. Originally, the TG group was composed of seventeen children as well, but three children had a severe language impairment, and inadequate text decoding skills (see Subsection 1.1).

Three comprehension exercises, CTxA, CTxB and CTxC, adopted the textual visualisation (see CTx in Section 3); the other three, CGrA, CGrB and CGrC, used the graphical visualisation (see CGr in Section 3). The TG group tackled first the CTx exercise set, and then the CGr exercise set; the GT group tackled the two exercise sets in inverse order. In this manner, we minimise the risk that time performance and accuracy depend on the order in which children resolve the exercise sets, CTx and CGr. The events used in the comprehension exercises were generated randomly from a set of seven extracted from the "The Ugly Ducking". In this manner, time performance and accuracy are independent of the event types and orderings.

One production exercise allowed children to only choose "before" or "after"; the other allowed children to choose any of the LODE relations for their stories.

Post-task interview.

After the computer session, we run a post-task interview using the sticky note critiquing method [Markopoulos et al., 2008]. Children worked initially in pairs or small groups. The teams had approximately ten minutes for writing their notes. Then the administrator commenced a discussion, approximately twenty-minute long, during which team member exposed and clarified their ideas further.

5.3 Results

Only one child declared not to use the computer at home, whereas the other children said they use it circa three times a week for about one hour; twenty-four of them are not allowed to use Internet alone at home. Background knowledge is an important factor, as it may improve the reading comprehension and reasoning on the story. During the post-task interview, the test administrator asked the children whether they already knew the story, and all answered they did. Only five children decided to read the story more than once.

5.3.1 Resolution Time Analysis

The average time of the computer session was about 25 minutes, out of which 6 minutes, averagely, were spent on the story. The test participants had no time limit for completing the computer session; they were also allowed to stop before finishing the tasks; however, none of them did it, all decided to read the story and tackle all the exercises.

The *resolution time* of an exercise is defined as the time that elapses since the child opens the exercise page until the child clicks the forward arrow—remember that the child can see and click the forward arrow only after correctly resolving the exercise.

Let $t(\mathrm{Ex})$ denote the mean resolution time of the Ex comprehension exercise, considering the TG$\cup$GT group of all the thirty-one children. Then Table 5.1 displays the value of the mean $1/3(t(\mathrm{CTxA}) + t(\mathrm{CTxB}) + t(\mathrm{CTxC}))$, and the value of the mean $1/3(t(\mathrm{CGrA}) + t(\mathrm{CGrB}) + t(\mathrm{CGrC}))$. Similarly, we obtain 111 seconds as the mean resolution time of the production exercises.

In order to assess whether the difference between the resolution times of the CTx exercises and CGr exercises is significant (see Table 5.1), we conducted an Analysis of Variance (ANOVA) with repeated measures. We considered the visualisation type as a within-subjects factor, since all the children had to resolve the same exercises, with two levels, textual or graphical. The main effect of the visualisation type was significant with $F(1, 30) = 14.797, p < .0001$. Thereby children had a significantly longer resolution time with the graphical visualisation than with the textual one.

Success Rate Analysis

As explained in Section 3, the comprehension exercises are 3-choice exercises. We consider a *comprehension exercise correctly resolved* if the child selects a consistent relation with: at most 2 choices in case of the CTxA and CGrA exercises, because these work as training exercises for the respective visualisation types; precisely one choice in the case of the other four exercises. The *success rate of a comprehension exercise set*, CTx or CGr, is then equal to the percentage of children that correctly resolved all the exercises of the set. Table 5.2 displays the success rates of the CTx set and CGr set. A binomial test revealed that the success rate was above chance with $p < .05$ for the CGr exercise set, and only at chance level for the CTx exercise set.

We consider a *production exercise correctly resolved* if the child composes a consistent story by making exactly 1 choice for each pair of events. The *success rate of the production exercise set* is then equal to the percentage of children that correctly resolved all the production exercises.

	CTx	CGr
TG∪ GT	24	43

Table 5.1: Mean resolution seconds for the comprehension exercises.

	CTx	CGr
TG∪ GT	51%	71%

Table 5.2: Mean success rates for the comprehension exercises.

The success rate of the production exercise set is equal to 74.2%. A binomial test revealed that this success rate was above chance with $p < .05$.

5.4 Discussion

The average success rates for the comprehension and production exercises gave us interesting information concerning the feasibility of the exercises. The success rates for the graphical comprehension exercises and the production exercises were greater than 70%, and above chance according to our analyses. These exercises, resolved in real time with a constraint programming system, are thus feasible for hearing novice readers, namely, 7–8 olds.

Also the analyses on the resolution times and success rates revealed some interesting results concerning the visualisation of the relations in the comprehension exercises. Hearing novice readers took significantly longer in dealing with the graphical visualisation than with the textual one, see also Table 5.1; however, only the graphical visualisation gave success rates above chance, and better than the textual one, see also Table 5.2. Given this, we can suppose that the greater time spent on the comprehension exercises with the graphical visualisation induced a deeper elaboration by the child; the support of graphical information may have induced a deeper analysis of the text, improving novice readers' comprehension. This hypothesis is consistent with the assumption that pictures or graphical information are superior to words and textual information in semantic tasks [Dillon and Song, 1997, Paivio, 1991].

On average, the test's children spent circa 33 seconds on the comprehension exercises (see Table 5.1) and 111 seconds on the production exercises; again, the fact that the children could only reason on textual information in the production exercises may have influenced their longer resolution times.

Chapter 6

Conclusions

The report outlined the architecture of LODE; for more details on this and the role of the constraint programming module, the interested reader is referred to [Gennari and Mich, 2007]. To the best of our knowledge, LODE is the first e-tool that employs an automated reasoner for reasoning, globally, on children's stories; for an overview of related literacy e-tools, see [Gennari and Mich, 2008c]. A first design of the GUI and a preliminary evaluation plan were described in [Gennari and Mich, 2008a]; then [Gennari and Mich, 2008b] reported on the evaluations of the tool with two deaf children and with experts of usability or deaf studies, that is, it reported on phase 1 described in Section 4. Note that the current production exercises, described in Section 3, were redesigned after phase 2, described in Section 4; they were evaluated for the first time as explained in this report.

The evaluation of the tool with hearing novice readers, presented in this report, allowed us to gather relevant information concerning the usability of the tool and, in particular, the feasibility of the graphical comprehension exercises and of the production exercises; see phase 3 in Section 4 and the discussion in Subsection 5.4. It will be interesting to see whether there are differences with deaf readers in this respect, and which.

In particular, the analyses performed in this report revealed that hearing novice readers took a significantly longer resolution time on the comprehension exercises with the graphical visualisation. However, their results with the graphical visualisation are above chance, and this visualisation is more comprehensible for them than the textual one. Such results suggest the following hypothesis: a child that lack proficient reading skills can better benefit from the graphical representation. The on-going evaluation also aims at assessing such hypothesis with deaf children.

In the on-going evaluation with deaf children, we are using the latest prototype of LODE but with more production exercises. We decided so because this evaluation also aims at assessing whether the children's time performance and accuracy depend on the type and number of temporal relations used in the production exercises; e.g., we expect to have worse success rates in the production exercises with all the LODE relations than in the production exercises with only "before" and "after". Another evaluation with hearing novice readers will be needed in order to compare these results on the production exercises.

To conclude, this study indicates that LODE and its reasoning exercises, developed with a constraint programming system, could be of aid in stimulating novice readers to reason, globally, on the temporal dimension of narratives. Future evaluations will assess such hypothesis and the efficacy of LODE.

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