iSTART-ALL: Confronting Adult Low Literacy with Intelligent Tutoring for Reading Comprehension

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Abstract. There is little empirical research available on the substantial problem of adult low literacy rates, and limited educational technologies are available to address distinct instructional needs of this population. This paper reports on development and testing of a version of Interactive Strategy Training for Active Reading and Thinking (iSTART) for Adult Literacy Learners (iSTART-ALL) We describe modifications of iSTART to accommodate adult literacy learners, including new practice modules (i.e., summarization, question asking), a new library of texts, and an interactive narrative for adult literacy learners to engage in extended practice of reading comprehension strategies. We report results of a study examining reactions to iSTART-ALL and performance data while engaging with the interactive narrative. The attitudinal study, conducted with 38 adult literacy learners, demonstrated generally positive reactions to the narrative. Results also revealed that task performance was strongly related to individual difference scores on reading comprehension assessments, and more so with higher-level comprehension skills than basic word-level skills, providing concurrent validity for the interactive narrative tasks.

Keywords: Intelligent tutoring systems • Interactive narrative • Adult literacy • Reading comprehension • Literacy technology

1 Introduction

The results of the Program for the International Assessment of Adult Competencies (PIAAC) conducted in 2012-2014 revealed that 17% of U.S. adults between 16 and 65 years old scored at or below the lowest level of the literacy scale (https://nces.ed.gov/surveys/piaac/results/summary.aspx). Furthermore, an additional 33% are at level 2, indicating performance well below functional literacy levels. Compared to the international average, the US had a higher percentage of adults performing at the lowest literacy levels. Even though findings such as these demonstrate an alarming need for empirically-based, effectual adult literacy instruction, there is a scarcity of rigorous research dedicated to this problem. To address this concern, our

team set out to identify unique educational needs of adult literacy learners and develop educational technology solutions tailored to those needs. We used an existing intelligent tutoring system for reading comprehension, the Interactive Strategy Training for Active Reading and Thinking (iSTART) as a foundation on which to develop iSTART-ALL for adult literacy learners.

iSTART delivers reading comprehension strategy training and extended strategy practice, using natural language processing to offer automated feedback. Originally developed to provide self-explanation strategy training for high school students, results demonstrate that iSTART improves self-explanation quality and performance on reading comprehension assessments [1,2]. The iSTART strategies (comprehension monitoring, paraphrasing, prediction, bridging inferencing, elaborating) have shown utility for readers with a wide range of ability [2]; thus, we expected iSTART to be effective for adult literacy learners. However, adult literacy learners have unique educational needs (e.g., low fluency and decoding skills; [3]); thus, we made several modifications and additions to the system. This paper focuses on the development and testing of an interactive narrative called 'Lost in Springdale'. The interactive narrative, or "choose your own adventure" story, offers learners additional opportunities to practice comprehension strategies using varied authentic text artifacts.

1.1 iSTART

iSTART provides reading comprehension training in two phases, *instruction* and *practice*. The instruction phase delivers a series of lesson videos covering self-explanation and five comprehension strategies (i.e. comprehension monitoring, paraphrasing, prediction, elaboration, and bridging). We have recently added summarization strategy lesson videos (i.e., deletion, replacement, main ideas, and topic sentences), as well as instruction on deep-level reasoning questions (i.e., how and why questions). We developed these additional instructional videos with the adult literacy population in mind; however, we expect they will promote reading for younger learners as well. After the instruction phase, learners advance to the practice phase, which offers generative and identification games to practice the reading strategies. Currently, we have practice games only for self-explanation strategies. In the generative games, learners read a text and type self-explanations for target sentences. iSTART provides automated feedback, using a natural language processing algorithm that compares self-explanation content to the target sentences, as well as previous and subsequent text content. In the identification games, learners see example self-explanations (along with the self-explained sentences) and attempt to identify which of the trained self-explanation strategies are used in the self-explanations. Empirical studies have demonstrated the effectiveness of iSTART to improve self-explanation skills and performance on reading comprehension measures [1,2] as well as science course performance [4]. Results further show that learners of varied reading skills can benefit from iSTART instruction [1,2], suggesting that the system holds promise for improving reading comprehension for the adult literacy population as well. Nonetheless, as the next section describes, we tailored elements of the system to make it more appropriate for this population.

1.2 Modifying iSTART for Adult Literacy Learners

In order to adapt iSTART more precisely to the needs of adult literacy learners, we applied user-centered design to make several modifications. First, we added strategy instruction for summarization and deep-level reasoning questions, and are in the process of developing practice games for those strategies. Next, we collected a new library of approximately 60 texts that are life-relevant (i.e., technology, health-related issues, family matters) to adult learners. Finally, we created the interactive narrative combining practice for self-explanation, summarization, and question asking.

Summarization and Question Asking Training. An analysis of the commonly-used adult literacy assessments [5] suggested that training summarization strategies can promote performance on The Adult Basic Learning Examination (ABLE), the Comprehension Adult Student Assessment System (CASAS), the Test of Adult Basic Education (TABE), and the General Educational Development (GED) exam. The summarization instructional modules present instruction on four effective summarization strategies [6,7]. Using the *deletion* strategy, learners remove unnecessary (i.e., trivial or redundant) information from the text. The substitution strategy involves identifying subordinate items in a list (e.g., apples, oranges, and bananas) and replacing the list with the superordinate category to which they belong (e.g., fruit). Using the *main ideas* strategy, learners identify the key points from the text that should be reflected in the summarization. Finally, learners can either identify or construct their own *topic sentence* to introduce the summary. The instructional videos on summarization include one overview of the strategies to be learned, four lesson videos on the strategies described above, and a recap lesson. These videos range from two to six minutes, for a total of 23.1 minutes of instructional time. We recorded human narration of the verbal instructional content and used the Prezi presentation software to develop the graphic content.

When learners generate questions about text, they can assess their comprehension of the material, [8,9] and the process of answering one's own deep-level questions can improve learning [10,11]. Deep-level questions, which require logical, causal, or goal-oriented reasoning [10], especially promote learning because they help the learner identify gaps in texts and their own comprehension. In fact, research has shown that viewing instructional videos using deep-level questions within dialogues can improve learning [12]. The three question asking instructional videos (1.5 to 5 minutes each; total time = 7.4 minutes) focus on instructing learners to generate deep-level reasoning questions, especially *how* and *why* questions concerning the causal mechanisms behind system functioning. The instruction describes the *value* of asking questions, supplies information about *how to apply* question asking strategies, and gives *examples* of deep questions.

New Library of Texts. Research shows that the content of texts plays an important role in interest, engagement and persistence, and learners are especially motivated toward content connecting to their knowledge and values [13,14]. Furthermore, the

average range of reading abilities identified for adult literacy learners is from 3rd to 8th grade. The texts in the previous versions of iSTART are difficult science texts (Flesch-Kincaid grade levels 6 to 14). Thus, we have collected a set of approximately 60 new texts from the California Distance Learning Project (www.cdlponline.org). The texts are simplified news stories on life relevant topics (e.g., housing, family, money) and range in difficulty from 3rd to 8th Flesch-Kincaid grade levels. These new text passages are used for both the generative and identification practice games.

Interactive Narrative. *Lost in Springdale* is an interactive first person narrative during which learners read several life-relevant artifacts and attempt to navigate the seemingly abandoned town of Springdale to find a friend from which they have been separated. In order to complete the narrative, the learner must visit three key locations (i.e., the Mall, School, and Hospital), encountering one Springdale resident at each (i.e., Elliot, Milo, and Violet, respectively). Learners select a character image from three females and three males to represent their friend and name the friend.

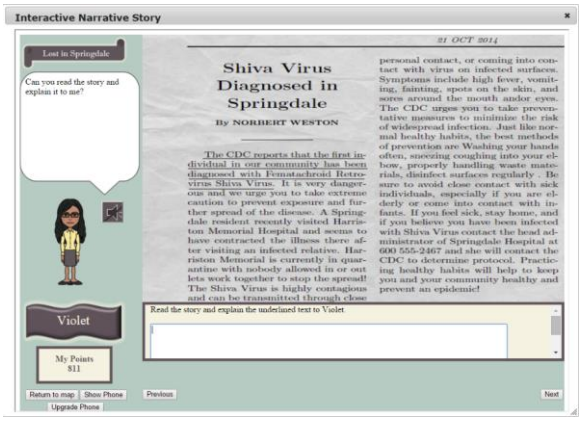

Fig. 1. Screenshot of an Artifact from the Interactive Narrative

Within the narrative, various life-relevant artifacts (e.g., school map, fire extinguisher instructions, update from the Centers for Disease Control [CDC], emails/letters) attempt to serve learning, assessment, and engagement goals. The interactive narrative provides instantiated practice of self-explanation, summarization, and question asking. After reading each artifact, the learner must answer a question, self-explain the text, ask a question about the text, provide a summary, or make a decision on where to go next. We selected life-relevant artifacts which could help learners in developing important life skills related to the three types of literacy identified by the NAAL: prose literacy (e.g., news stories), document literacy (e.g. drug labels), and quantitative literacy (e.g., food labels). Figure 1 is an example artifact in which the learner writes a self-explanation of a news story on a CDC virus update. Character speech is provided visually and auditorily (which can be muted depending on learner preference). For each artifact, the learner receives immediate feedback, including hints and corrective feedback (at bottom-out). As the learner progresses through each of the three primary story arcs, the tasks become more difficult; texts

become longer and more complex, and responses change from binary decisions, to four-choice multiple-choice questions, and ultimately, to open-response items (e.g., short answers, self-explanations, and summaries). The system will provide automated feedback for open-response items using natural language processing (NLP) algorithms. The self-explanation assessment algorithm used in other self-explanation activities in iSTART [15] is implemented. We are in the process of developing NLP algorithms for assessing students' summaries and generated questions [16]. When a task is successfully completed, the learner earns points; the number of points depends on the sophistication of the reasoning skill, the type of learner response, and the complexity of the text or image.

Learners' responses to each artifact determine the subsequent flow of the storyline. For example, in the Introduction, the learner must decide whether to stay with the broken down car (while the friend investigates a nearby house), or to go investigate the house (while the friend stays with the car). Which pages are shown subsequently depends on the learner's decision in this situation. Additionally, the learner is given the choice of which segment of the story to read at any time (i.e., Mall, School, or Hospital). The town map is presented after the introduction segment of the narrative, which establishes the overall premise of the story. By clicking on an image that represents a location (e.g., the Mall), the learner can go to a new town location. This design facilitates interactions with our target population by allowing for simple, visual, non-language dependent interface navigation.

Learners have access to a cell phone during the interactive narrative, which provides several assistive and motivational features. First, at predetermined moments in the narrative, the cell phone automatically 'takes photos' of scenes and artifacts, and the system saves the photos to the photo album. Previously-saved photos can be accessed from the cell phone at any time. Next, the cell phone can be used to type electronic notes, which are saved in the phone's notes feature. The cell phone also provides a simple open learner model to track learning progress using two sets of skill-o-meters, one representing mastery of domain knowledge (e.g., health, mechanical skills) and one representing mastery of the reading and thinking skills (e.g., self-explanation, summarization). The fill of each skill-o-meter is determined by the proportion of correct answers for each category. This feature was designed to promote reflection on learning and help plan future behavior in the system. Finally, points scored in the narrative can be used to purchase trendier models of phones. We included this functionality to increase investment toward successful task completion (i.e., to score points) and to investigate off-task behavior and personalization activities.

2 Method

2.1 Participants

Participants included 38 adults recruited from three adult literacy programs in the Southwestern region of the United States and who were paid for their participation. The mean age of the participants was 34 (*SD* = 13.22; range 18-65), and the majority of the participants were female (76.3%). Participants self-identified as Hispanic

(57.9%), African American (15.8%), Caucasian (15.8%), and 10.5% as other. Most declared English as their native language (65.8%) while 31.6% identified Spanish and 2.6% as other. Although participants were recruited from General Educational Development preparation classes, they represented a variety of education backgrounds: 52.6% did not graduate high school, 29.0% graduated high school, 7.9% received a GED, 7.9% completed some college, and 2.6% graduated from a 4-year college.

2.2 Measures

Participants completed a series of reading comprehension measures. On the Gates-MacGinitie Reading Comprehension subtest (level 6) [14] the sample performed at a mean grade equivalency of 7.27 (SD = 2.47). By comparison, participants scored a mean grade equivalency of 10.1 (SD = 2.95) on the Gates-MacGinitie Vocabulary subtest [17], indicative that the participants were more able to understand words, and less able to comprehend sentences and connected discourse. Testing also assessed morphological and semantic awareness using the Test of Morphological Structure - Decomposition and Derivation sections [18]. The proportion accuracy was .85 (SD = .17) and .61 (SD = .21) respectively.

iSTART logs participants' behavior throughout interactions with the system, including participant responses to each artifact question. A proportion correct score was obtained by dividing the number of correct responses by number of responses. Further, an analogous proportion correct score was calculated for each story arc.

A post-survey was administered to assess participants' enjoyment of the system and its features (e.g., "I enjoyed reading the story") as well as their engagement in the task (e.g., "I set goals for myself during the story"). Participants answered these survey items on a 5-point Likert Scale. In addition to these overall ratings of the participants' perceptions of the narrative, they also responded to four 4-point Likert Scale items for each of the story arcs: 1) How difficult did you find the tasks you completed in the X (e.g., Introduction)?, 2) How useful did you consider the tasks in the X?, 3) I found the X segment of the story engaging, and 4) After reading the X, I was interested to find out what happened next in the story.

2.3 Procedure

The study was conducted over two sessions. In the first session, participants responded to a battery of reading comprehension measures. Next, the participants viewed six short videos briefly describing self-explanation, summarization, and question asking. In the second session, participants completed the interactive narrative and a post-experience survey. Participants who completed the story (n = 33) spent an average of 105.4 minutes (SD = 27.2). Five participants did not finish reading the entire story, spending an average of 122.4 minutes in the system (SD = 7.98). Within individual story arcs, participants' completion times varied: Introduction (M = 2.9; SD = .72); Mall (M = 25.2; SD = 7.2); Hospital (M = 34.5; SD = 15.12); School (M = 26.2; SD = 9.3); Conclusion (M = 14.6; SD = 4.1). After completing the interactive narrative, the participants completed questions regarding their perceptions and attitudes.

3 Results

3.1 Perceptions of the Narrative

Results revealed generally positive attitudes toward the interactive narrative. Figure 2 presents frequencies of the responses from Strongly Disagree (1) to Strongly Agree (5) on the five overall perceptions of enjoyment and engagement. A series of one-sample t-tests revealed that mean ratings for each of these items were significantly higher (all p's < .005) than the mid-point of the scale (i.e., 3), indicating that participants leaned toward the 'agree' end of the scale for these positive perception statements about the story. The majority of participants responded either 'agree' or 'strongly agree' to the following statements: 1) I enjoyed reading the story (75.0%), 2) The feedback was helpful (69.4%), 3) The interface had game-like features (62.2%), The environment provided a purpose for my actions (78.4%), The visual parts of the environment made the story more enjoyable (75.7%), The objects in the environment were easy to control (67.6%), I wanted to perform well during the story (81.1%), and I would use this environment to practice other skills (75.7%).

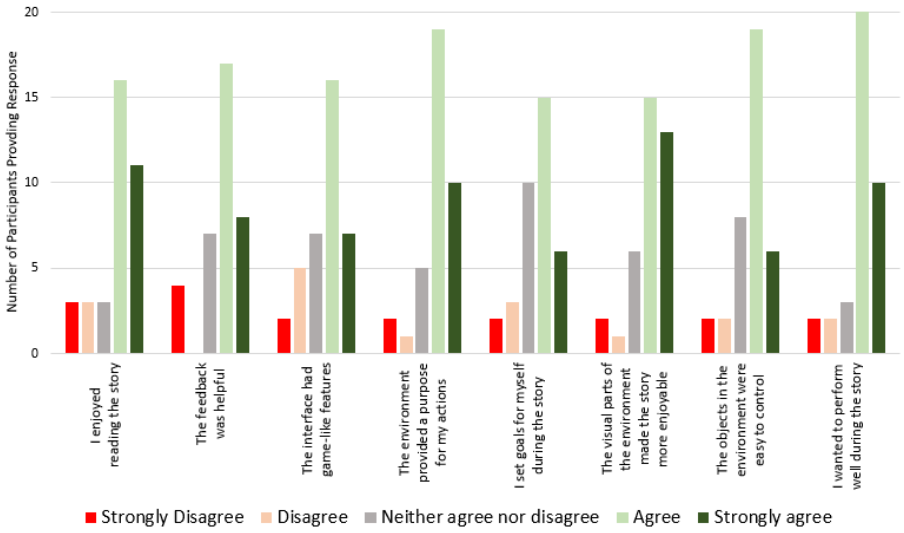

Fig. 2. Overall Perceptions of the Narrative

We further conducted analyses on participants' perceptions toward the individual story arcs. Figure 3 shows frequencies of responses on the difficulty item, across the story arcs. One-sample t-tests revealed that mean ratings of difficulty were significantly lower than the mid-point of the scale (i.e., 2.5) for all story arcs (all p's < .001).

Figure 4 shows the frequencies of responses for the usefulness item, across story arcs. The one-sample t-tests revealed that mean ratings of usefulness were significantly higher than the mid-point of the scale for each story arcs (all p's < .001). Corresponding analyses were conducted for the engagement (see Figure 5) and interest (see

Figure 6) items. Results revealed that mean ratings of engagement were significantly higher than the mid-point of the scale for all story arcs (all *p*'s < .001), and the same was true for interest ratings (all *p*'s < .001).

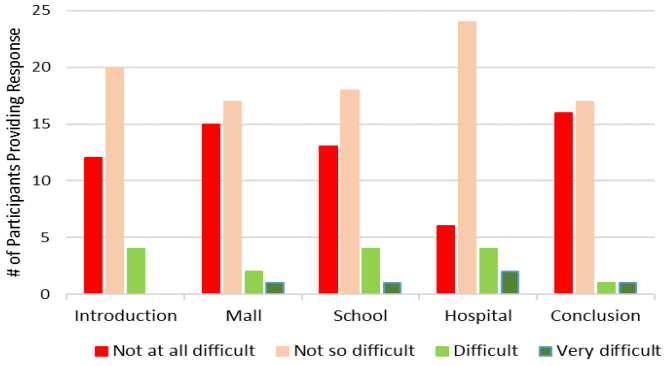

Fig. 3. Difficulty Ratings of the Story Arcs

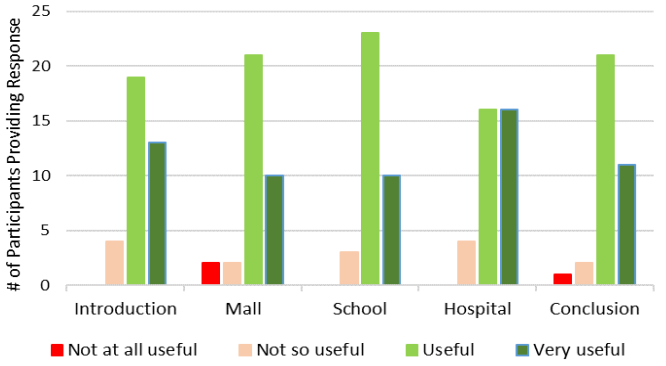

Fig. 4. Usefulness Ratings of the Story Arcs

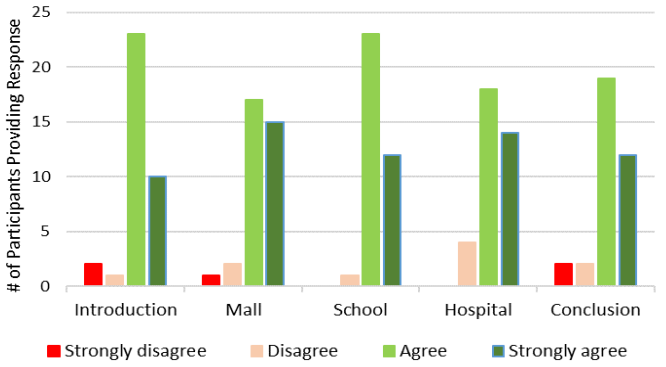

Fig. 5. Engagement Ratings of the Story Arcs

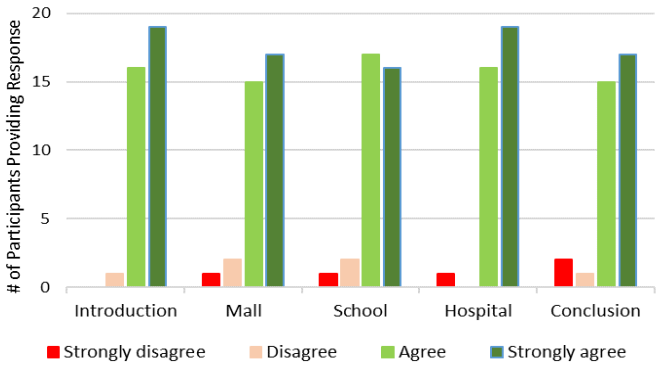

Fig. 6. Interest Ratings of the Story Arcs

3.2 Online Performance Measures

Exploration of participants' performance in the system began by examining the percentage correct on artifact items, across each participant's entire session. Overall, participants provided the correct response on a mean of 66.5% (*SD* = 8.8%) of items. This overall performance indicates that the difficulty of the tasks was acceptable for this population. This performance level seems to contradict the self-reported difficulty ratings reported earlier, indicating generally low ratings of difficulty. Hence, we conducted a series of correlations between the overall percentage correct and the difficulty ratings for the story arcs. None were significant, and all were below .20, which is consistent with research on students' tendency to miscalibrate their performance [19].

Four of the story arcs included items with response accuracy (i.e., which could be scored as correct or incorrect). The Introduction segment did not include any such items. Performance appeared to differ across the four story arcs: *M*(Mall) = 65.0% (*SD* = 10.3%), *M*(School) = 72.7% (*SD* = 12.0%), *M*(Hospital) = 68.4% (*SD* = 14.7%), *M*(Conclusion) = 61.0% (*SD* = 16.0%). A repeated-measures ANOVA revealed a significant effect of story arc on these performance scores, $F(3,99) = 7.20$, $p < .001$, $\eta_p^2 = 0.18$. Pairwise comparisons showed that scores were significantly higher for the School arc, compared to the Mall ($p < .001$), and compared to the Conclusion ($p < .001$). Additionally, scores were higher for the Hospital, compared to the Conclusion ($p < .05$). There were no other significant comparisons. We further sub-divided the artifact questions into types of questions. Across the four story arcs containing evaluative questions, 44 questions were multiple-choice items and 8 were select all or drag-and-drop questions. We expected performance to be lower for select all/drag-and-drop questions; results confirmed this: *M*(multiple-choice) = 72.9% (*SD* = 9.2%), *M*(select all/drag-and-drop) = 30.4% (*SD* = 20.7%), $t(37) = 12.33$, $p < .001$, $d = 2.19$.

One of our questions regarded the degree to which performance on the artifact questions within the narrative would correlate with participants' scores on the individual difference measures. Positive correlations would be indicative that the tasks within the narrative were tapping into the comprehension skills targeted in iSTART, and thus provide one source of concurrent validity. To address this question, we con-

ducted a series of bivariate correlations between the individual difference measures in reading (Gates reading, Gates vocabulary, Test of morphological structure – decomposition, and Test of morphological structure – derivation) and the overall narrative performance score, the narrative multiple-choice score, and the narrative select all/drag-and-drop score (see Table 1). Not surprisingly, the correlation between the two Gates measures was strong, as was the correlation between the two morphological structure measures (r = .79). Also, the correlation between all narrative items and the (n = 44) multiple-choice items was very strong (r = .95) compared to the correlation between all items and the (n = 8) select all/drag-and-drop items (r = .43), primarily because there were more multiple-choice items comprising all items. Of particular interest to our development efforts, the correlation between the Gates reading measure and all narrative items was strong (r = .60), indicating that the items in the story are suitably evaluative of reading comprehension ability. Correlations between performance in the narrative and the morphological structure measure, and the Gates reading measure were comparably lower, suggesting that the narrative items relate more toward higher-level comprehension skills than basic word-level skills.

Table 1. Correlations for individual difference measures and narrative performance scores

	2	3	4	5	6	7
1. Gates Reading	.614 ***	.431**	.393*	.599***	.493**	.499**
2. Gates Vocabulary		.428**	.424**	.411*	.313	.351*
3. TMS-Decomposition			.787***	.264	.189	.244
4. TMS-Derivation				.221	.140	.205
5. All Narrative items					.953***	.431**
6. MC Narrative items						.157
7. SA/DD Narr. items						

*** Significant at the 0.001 level ** Significant at the 0.01 level * Significant at the 0.05 level

Notes: TMS= Test of Morphological Structure; MC = multiple-choice; SA/DD Narr. items = Select All/Drag-and-Drop Narrative Items

4 Conclusions

This paper describes the development of iSTART-ALL for adult literacy learners. We focused the description on design, development, and testing of the interactive narrative developed to provide extended practice of reading comprehension strategies. The narrative, designed as a new practice module in iSTART-ALL instruction, was informed by prior recommendations [20]. We created the learning artifacts in the narrative to target life-relevant skills for low literate adults, and used the following design elements to ensure its effectiveness in improving adults' reading comprehension:

- The storyline is adaptive to learners' decisions
- Learning artifacts are life-relevant to adult learners to develop life skills
- The system uses a variety of interaction methods and response types
- Motivation elements are used to enhance effort and persistence
- An open learner model is used to promote reflection on learning

- Foundational skills (e.g., decoding) are supported with pronunciation scaffolding and auditory text presentation

The results from an attitudinal study conducted with adult literacy learners indicated overall positive perceptions of their experiences with the narrative. Over 60% of the participants responded 'agree' or 'strongly agree' to a series of positive statements about the module. Although the participants tended to rate the segments of the story as not very difficult, performance data within the system indicated a mean percent correct of 66.5%; thus, we believe the difficulty of the items is appropriate for this population. The conclusion story segment appears to be the most difficult, perhaps because it includes items requiring participants to remember what happened in earlier-read segments and to determine the sequence of events that led up to the abandonment of the town. Interestingly, though, students did not rate the conclusion segment as more difficult than the other parts of the story, perhaps because they were not required to read new learning artifacts during the conclusion.

The correlations between the individual difference measures and the online performance data were indicative of strong relations between students' reading ability and narrative performance. This finding establishes tentative concurrent validity for the tasks within the narrative, and further suggests that the tasks provide indicators of reading comprehension abilities. As such, the difficulty of the texts and the question types (e.g., multiple choice vs. open-ended) can potentially be iteratively adjusted according to individuals' performance on the tasks. Future development plans also include refining the NLP assessment algorithms for students' summaries and questions and to use those algorithms to provide automated feedback.

Of course, this study is only a first in a series of those that we envision. Most importantly, empirical evidence of effectiveness is crucial. For example, a study is currently underway to examine the effects of iSTART-ALL on adult learners' motivation and reading comprehension abilities. Nonetheless, the current study provides an important stride and preliminary evidence for the potential promise of iSTART-ALL to meet the unique needs of adult literacy learners.

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