Integrating SARA Assessment with Reading Comprehension Training in AutoTutor

E. Halle Smith, John Hollander, Art C. Graesser, John Sabatini, and Xiangen Hu[*]

Facing the demands of the pandemic and distance learning, English learners require educational technologies that are accessible, engaging, and effective. Meeting these demands requires educational technology developers to consider learners' sociocultural contexts. Learning theories can be applied to meet individuals' needs to optimize chances for participation, engagement, and learning gains. This article describes two Internet-based digital technologies that target struggling adult readers who need to improve their comprehension skills: SARA (Study Aid and Reading Assessment) and AutoTutor for Adult Reading Comprehension. The SARA assessment provides a diagnostic profile for individuals' reading strengths and weaknesses. This profile can be used to guide the selection of reading comprehension lessons in AutoTutor-ARC, a digital technology that both adapts to learners' performances and engages them in an immersive learning experience using a three-way conversation with computer agents acting as a tutor and a peer to discuss texts. We discuss how these technologies can be integrated into educational settings to improve engagement and learning.

Key words: reading assessment, reading comprehension, assessment, adult literacy, English literacy

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*First Author: E. Halle Smith, Research Coordinator, Institute for Intelligent Systems, University of Memphis

Corresponding Author: Art C. Graesser, Emeritus Professor, Institute for Intelligent Systems, University of Memphis; 365 Innovation Drive, Suite 303, Memphis, TN 38152-3115, U. S. A; Email: graesser@memphis.edu

Co-authors: John Hollander, Graduate student, University of Memphis; John Sabatini, Professor, University of Memphis; Xiangen Hu, Professor, University of Memphis

1. INTEGRATING SARA ASSESSMENT WITH READING COMPREHENSION TRAINING IN AutoTutor

Digital education technologies on the Internet have played an increasingly important role in the teaching of English all over the world, especially over the last decade. The recent COVID-19 pandemic has shone a spotlight on the demand and immediacy of these technologies. Without the ability to rely on traditional, face-to-face education techniques, much of the world has been forced to use digital technology as the primary medium of learning. The ability to make educational technology that is accessible, engaging, and effective has become more than a goal; it has become a necessity.

The challenges posed to educational technologies in the teaching of English are in many ways similar to those in other educational fields, but it could be argued that language education (including, but not limited to English) faces some distinctive obstacles. Immersion is well-known to be an extremely important and effective element of learning a second language, but achieving immersion is difficult without face-to-face communications that facilitate processing gesture, facial expressions, and speech intonation. Communication technologies such as Skype or Zoom can help fill this gap, although there are limitations on speakers' being positioned in front of the camera and typically only showing their faces. Nevertheless, these obstacles may be seen as opportunities for digital educational technologies to grow and become reimagined to address the needs of more teachers and learners through the pandemic and beyond. Advances as a result of these demands will make digital educational technologies more accessible to teachers and students of all levels, more engaging and immersive, and more adaptive and accommodating to the individual needs of each learner. This is especially true of English education, which requires these elements to be maximally effective.

Education that is engaging, adaptive, and effective also requires awareness of the history and sociocultural context of individual learners. According to the report on *How People Learn* II from the National Academy of Sciences, Engineering, and Medicine (NASEM, 2018), culture informs what knowledge takes priority within day-to-day demands as well as what knowledge is practical to acquire. There are important implications of a sociocultural perspective on retention and attrition. Learners will drop out or become disengaged when there is a conflict between a learner's culture and the educational curriculum. Adaptive, engaging education requires some assessment of the learner's knowledge, skills, and abilities so that the educational activities are not too difficult or too easy. Adaptive, engaging education requires tailoring to the learner's motivation, goals, and needs.

This article describes two digital technologies on the Internet that were designed to adapt to learning needs to help adults with low reading comprehension skills in the English language. One system, called SARA (Study Aid and Reading Assessment), is a

multicomponent reading skills assessment that identifies the strengths and weaknesses of individual readers in the English language. The other system, called AutoTutor-ARC (Adult Reading Comprehension), has thirty lessons that train adult readers on comprehension skills and strategies in the English language. Our emphasis on comprehension reflects practical needs. Comprehension skills are particularly difficult to teach without substantial expertise and experience by the instructor, and there is a limited supply of expert instructors. Improving reading comprehension skill development in adults is important because it is a major requirement for employment in higher-paying jobs in the 21st century (Autor, Levy, & Murnane, 2003). Our emphasis on adults also reflects practical considerations. Throughout the world, there are many individuals who desire training on reading comprehension skills in the English language. Even in the United States, one out of six adults has low literacy skills (OECD, 2013). There is a very high drop-out rate of adult readers for a variety of reasons (Greenberg, 2008; Sabatini, Shore, Holtzman, & Scarborough, 2011) so it is important to optimize the engagement of readers in addition to their performance in a learning environment.

2. INDIVIDUALIZED EDUCATION

Everyone agrees that individualized instruction is an improvement over a common "one size fits all" approach in a classroom of many students. That is why one-on-one tutoring is a common practice, although expert tutors are in short supply (Graesser, Rus, & Hu, 2017). How do we define individualization in English reading education? English reading comprehension is typically treated as a singular skill in both child and adult educational practice. This treatment neglects the mechanics behind the learner's reading comprehension and may result in overgeneralized instruction approaches for learners with diverse backgrounds and characteristics. In other words, individuals who score poorly on reading comprehension measures may lack certain foundational reading skills. Using generalized reading interventions exclusively without incorporating individualized instruction may result in little to no English language learning, especially at a conversational level (Doughty & Long, 2003). Furthermore, K-12 dominates the vast majority of reading instructional material. Yet, adults with low literacy may use reading component skills and strategies differently than do children of equivalent overall reading comprehension abilities (Binder, Talwar, Bond, & Cote, 2019; Sabatini, O'Reilly, Dreier, & Wang, 2019). These differences in children versus adults suggest that instruction designed solely around children's reading comprehension would therefore likely be less effective for adult readers.

The lives of adults are obviously very different from the lives of children. Children are typically in classroom settings whereas adults have a more diverse spectrum of learning

contexts. Distance learning can serve adults' specific needs by extending education beyond the boundaries of the classroom, accommodating complex schedules and consequently building the opportunity to integrate education when learners feel ready to engage and at their convenience.

3. DIGITAL TECHNOLOGY APPLICATIONS

Two digital technologies have been developed to help struggling adult readers improve their English comprehension skills. The first is SARA (Sabatini et al., 2019b) for reading assessment, and the second is AutoTutor-ARC, an intelligent tutoring system with conversational agents for the training of reading comprehension skills (Graesser, Greenberg, Olney, & Lovett, 2019). These two systems are integrated into a single education environment (https://arcweb.us). SARA assesses the adults on several reading foundational skills and passage comprehension. If the adult has sufficient skills in word decoding and other basic reading skills, they move to AutoTutor-ARC to receive reading comprehension training.

3.1. SARA

To determine what lessons may be best suited to a learner's needs, teachers can use assessments as a diagnostic tool for an individual, rather than as a descriptive measurement of a group. Reading comprehension involves the intricate use of multiple overlapping skills (Perfetti & Adlof, 2012) ranging from the visual identification of letters and words to the construction of complex situation models of text meaning. Understanding a learner's strengths and weaknesses in foundational reading skills can inform effective instruction. For this purpose, we reference SARA (Study Aid and Reading Assessment), a component reading skills assessment designed to identify the strengths and weaknesses of individual learners. SARA is a free and publicly available test battery for adult learners. It is composed of five multiple-choice subtests measuring foundational reading components. The theoretical model underlying the set of subtests is psycholinguistic, thus elements of English language knowledge and skills (e.g., morphology, vocabulary, grammar) are measured in specific subtests. A sixth multiple-choice subtest assesses general reading comprehension. This assessment structure results in a data-rich profile of each learner's strengths and targets for improvement. The subtests' scores and the reading skills profile are immediately available to the teacher. In this way, SARA is not only an assessment but also an integrative instructional tool that can provide information about the individual needs of students that English language educators can easily utilize in instruction and tutoring.

Measuring the strengths and weaknesses in reading subskills affords the ability to make targeted instructional strategies aiming to maximize literacy and educational gain. Each subtest typically takes less than ten minutes to complete for most developing readers; for each tested reading component, there are exercises and instructional strategy recommendations (and AutoTutor-ARC lessons) to benefit the learner. The component subtests include:

Decoding and Word Recognition tests a learner's knowledge of sight words and novel word decoding (Ehri, 2005), or the ability to sound out novel words based on known phonemic spelling patterns. In all readers, these skills are crucial for learning new vocabulary. With accumulated experience, skilled readers can process frequently experienced words without the need for additional context, freeing up cognitive resources for more complex processing (Perfetti, Van Dyke, & Hart, 2001). Specific difficulties in mastering decoding skills may be indicative of reading disability, dyslexia, or unfamiliarity with English phonology (Olson, 2007; Seidenberg, 2017). Low scores in word recognition and decoding may imply that a reader is unfamiliar with orthography-phonology correspondences in English.

Vocabulary tests a learner's knowledge of print word meanings. This subtest assesses general-purpose academic words and concepts. Further, the subtest targets both synonyms and secondary meanings for academic words, as well as topical associations (e.g., forest to tree), which is an indicator of relevant knowledge activation. Vocabulary is known to have a strong correlation with overall text comprehension (Perfetti, 2007). Low scores in vocabulary imply a lack of experience with common academic concept words in English.

Morphology tests a learner's knowledge of how the building blocks of words influence both word and sentence meaning. Morphological knowledge has been recognized as a distinct and vital component of literacy development (Nagy, Berninger, & Abbott, 2006), especially for English-language learners (Kieffer & Lesaux, 2008). Evidence suggests that instruction designed to improve morphological awareness increases overall reading comprehension outcomes (Proctor et al., 2011). Low scores in morphology suggest a lack of experience with English morphosyntactic rules and grammar.

Sentence processing tests a learner's ability to understand the relationships between words in sentences of varying complexity. This subtest captures the ability to integrate syntactic and semantic information to build meaning from sentences, which is critical but often challenging to developing readers in building their comprehension of longer text passages. (Carlisle & Rice, 2002). Processing relation-signaling words (e.g. *because*, *if*, *although*) are a key element of this subtest, as they have been found to be particularly diagnostic of struggling readers (McClure & Steffensen, 1985). Low scores in sentence processing imply a lack of experience or understanding of discourse-modifying, relation-

signaling, and logical operator words. Further, low scores in sentence processing might suggest that a reader is struggling to build a situation model based on the relationships between concepts and words, regardless of their ability to recognize them individually.

Reading efficiency tests silent reading fluency and efficiency when reading text passages. Skilled reading is both fast and accurate, which is dependent on not only possessing certain component skills but also their synchrony and orchestration. This task design is widely used for progress monitoring and has been found to be strongly correlated with comprehension (Shin, Deno, & Espin, 2000; Wayman, Wallace, Wiley, Ticha, & Espin, 2007). Low scores in reading efficiency may indicate effortful reading, implying that one or more of the previously mentioned skills are either weak or not integrating rapidly.

Reading comprehension is a condensed version of traditional, passage reading comprehension assessments. This version is designed to assess a learner's surface-level and gist-based understandings of brief passages (Kintsch, 1988). In this way, readers are not asked to make conceptual or social inferences about the reading material, which would demand domain knowledge beyond basic comprehension skills. Rather, learners are asked to locate, paraphrase, and make low-level inferences about the passages presented.

In discussing these subtests and the implications of their scores, we emphasize how digital educational technology can be used and integrated seamlessly into a teacher's strategy; seamlessly, because SARA is designed to be flexible to the teacher's needs and resources. It makes it possible, in the short period of allotted time to the classroom, to assess and accommodate an individual learner's needs.

There are several empirically evaluated and found to be psychometrically sound SARA forms at multiple levels of difficulty, underscoring the importance of adaptability and sensitivity to the needs of each learner. Further, SARA has been shown to be a reliable assessment for both native English speakers and English Language Learners (Sabatini et al., 2019b). When learning English, these underlying cognitive abilities are especially important to account for because of the highly irregular sight–sound correspondence patterns of the English language. Personalized learning begins when teachers fully understand the strengths and weaknesses of their students. By accounting for these nuances with in-depth, individualized assessments like SARA, learning gains can be maximized for every student.

3.2. AutoTutor-ARC

AutoTutor-ARC (hereafter AutoTutor for short) is an intelligent tutoring system with agents that simulate tutors and fellow students in conversations with the adult learner about text they are trying to comprehend (Graesser et al., 2019). AutoTutor is administered through a stable Internet connection on any computer and is hosted on a learning management system to enable teachers and learners to use the system (https://arcweb.us).

AutoTutor offers thirty lessons utilizing a wide range of English language activities and environments. These lessons can be recommended in any order and number by a teacher to personalize a curriculum for an individual student based on strengths and weaknesses. Alternatively, the students can take the initiative to select their own lessons, but that currently is a rare occurrence in U.S. literacy centers. Using AutoTutor in this way emphasizes its role alongside teacher instruction: educational technology need not replace an instructor, but it can supplement instruction, especially in a field with limited resources. Research conducted on the use of AutoTutor in hybrid learning environments with human instructors confirms that it supports reading comprehension gains in most categories of struggling adult readers in pretest-posttest comparisons on standardized comprehension tests (Fang et al., in press).

3.2.1. Features

AutoTutor has thirty lessons with *trialogues* (one adult interacting with a tutor agent and a peer agent) that were designed to teach comprehension strategies across different levels of discourse processing that include words, the explicit text, the deeper situation model, and rhetorical structure (Graesser & McNamara, 2011; Kintsch, 1998), as well as handling forms/documents and digital media. Each lesson takes between 15 and 50 minutes to complete. The agents frequently ask questions in the conversation-based training; a user's performance (time and accuracy of answering questions) is stored in computer logs. Additional agent dialogue includes feedback, hints, explanations, and corrections. Unlike previous AutoTutor applications (Graesser, 2016), AutoTutor has limited natural language extraction because most struggling adult readers have difficulty producing text. Consequently, the recorded behaviors are clicks and the sliding of words, texts, or images.

AutoTutor records each student's answers and the amount of time it takes to answer the questions that are woven into the trialogue conversations about text. AutoTutor is adaptive to individualized student performance. Students who consistently perform strongly will be directed to more challenging material, while students who struggle with a lesson will be given easier activities and more guidance from the conversational agents. The difficulty of texts is scaled according to a system called Coh-Metrix (Graesser et al., 2014) that automatically analyzes text complexity on multiple levels of language and discourse (cohmetrix.com). Using accuracy and temporal data patterns, AutoTutor is sensitive to different types of learners, including proficient (fast and accurate), struggling (slow and inaccurate), conscientious (slow and accurate), and under-engaged (fast and inaccurate) readers (Fang et al., in press).

Personalization to the learner also requires accessibility features. To accommodate the diversity of learning needs of a heterogeneous learning population, digital technology for education must also be designed with accessibility in mind. Further, web-based educational

technologies must account for all levels of digital skill levels and English language skill levels in learner populations to be accessible and beneficial to learners of all backgrounds.

The interface of AutoTutor is empirically grounded in studies that have examined the prevalence of specific computer skills in adults who participate in adult literacy education programs (Olney, Bakhtiari, Greenberg, & Graesser, 2017). Further, each time a new computer skill is required, such as clicking, typing, or scrolling, learners are presented with a short, repeatable tutorial that demonstrates and allows for practice and acclimation. These tutorial sections are narrated and captioned in English, allowing learners to gain exposure not only to lesson material but also to functional English used to describe basic digital skills and environments.

In addition to these features, AutoTutor contains other accessibility accommodations. Lessons begin with instructive videos that encourage relevant reading strategies which can be viewed repeatedly throughout each activity. Subtitles of all narrations and dialogue are available if learners struggle with any element of spoken English. Text on the screen that is not a part of narrations or dialogue can be read aloud by the system at any time. Reading material is often accompanied by visual aids, including pictures, diagrams, and multimedia presentations that facilitate comprehension and engagement. By offering such accommodations, the commitment to accessibility and personalization remains a key element and goal for improvement in this and many other English language educational technologies.

For teachers, accessibility comes with the website design minimizing demands to instructors' resources and energy expenditure puzzling out how to make the technology work. Teachers receive a free teacher account on https://arcweb.us. After registering, the instructor will receive access to login information for their teacher AutoTutor account as well as a roster spreadsheet of student login information. The instructor will also receive a link to step-by-step instructions for navigating the AutoTutor website. This process was designed to make it as simple as possible for teachers to learn and use the system.

For students, accessibility comes alongside the website design, and more significantly, the content. To begin with, after taking an introductory lesson giving instructions on basic skills necessary to navigate AutoTutor, the student has access to the thirty lessons that focus on particular skills improving reading comprehension. Each learner is provided access to a chart tracking their progress through AutoTutor lessons. This chart lists which lessons the learner has opened and when they took them. It also provides a link that uses a learner's recorded score to report whether the learner should retake the lessons or continue a lesson they began previously.

AutoTutor accommodates adults of multiple digital skill levels and educational backgrounds in several ways. It accommodates distance needs by encouraging alternate modes of communication between teachers and students. It provides access to an in-system

email facility to enable remote communication between learners and their instructors. This system is especially useful given that it removes the necessity of navigating to external platforms (e.g., email platforms like Gmail and Outlook) during use of the AutoTutor system. However, removing the necessity does not remove the opportunity. Indeed, some teachers may prefer to communicate with common technologies readily and easily accessible to students, such as cell phone texts. Use of the in-system email provided in AutoTutor is one path for the instructor to communicate directly with students.

3.2.2. Engagement

Engagement is and should be a core principle of the design behind any educational technology. AutoTutor was designed to optimize engagement in several ways. First, it simulates a social environment through actively engaging the learner in trialogues with tutor and peer agents. Conversation has been the primary foundation of learning throughout history until the printing press arrived; the agents provide this pedagogical conversation in the presence of text to be comprehended. Second, the different discourse structures of the conversation encourage engagement. The agents can take the roles of both tutor and peer. In the role of a tutor, the agents provide positive feedback, encouragement, and guidance. In the role of a peer, the agents model and scaffold learning behaviors, introduce different ways of thinking about the material, and provide supportive commentary. The agents sometimes arrange a friendly competition between the learner and peer agents, awarding points for correctly answered questions, including additional points for more difficult questions. These competitions adapt to the learner's performance such that the learner always eventually wins, which is designed to support self-efficacy, confidence, and engagement. Third, students enter their names into the system, allowing the agents to call their names, individualizing the learning experience, and creating a more immersive environment. This type of dynamic, immersive environment may be especially helpful to English Language Learners, who may gain extra experience with conversational English beyond the words printed on each screen.

Other features were also implemented to optimize engagement. The materials cover topics of interest or value to adults, such as job applications, rental agreements, medical information, cooking recipes, sports, adult-oriented stories, researching topics using the internet, and using email and social media. Each lesson is built to align with the College and Career Readiness Standards for Adult Education (Pimentel, 2013). This content builds skills that support success and engagement beyond the walls of the classroom. The generation of many of the text materials is also adaptive to the students' performance by starting with a lesson medium in difficulty and by branching out to more difficult or easier materials depending on their performance. Regarding discourse modality, texts can be read to the students by agents or a recorded human when the student has trouble comprehending a printed text. The

materials have many visual images that are integrated with text, which is important in the age of multimedia.

Chen et al. (2021) analyzed the engagement of students in using AutoTutor in a four-month intervention with 252 struggling adult readers in Atlanta and Toronto. Engagement could be detected within a two-minute time window based on the performance of the students in answering questions woven into the trialogue conversations (namely, answer correctness and response time). The observations in which students were engaged, according to an intelligent algorithm, robustly predicted comprehension learning gains on three psychometric tests of comprehension (including SARA); the unengaged observations did not predict learning gains, as would be expected. In this way, we can tell, in a two-minute span of time per lesson, when students are engaged.

4. FUTURE RESEARCH

Increasingly, literacy skills are needed not only for conventional printed materials but also in accessing, searching, navigating, and learning from digital sources (PIAAC Literacy Expert Group, 2009), At this point, AutoTutor and SARA both exist solely on web-based platforms, which require a computer connected to the internet to access. Many adult learners are limited in their access to computers or may have limited digital skills in using them. For this reason, we are developing digital literacy modules to ensure that users have the hardware, mouse, keyboard, and navigational skills necessary to navigate AutoTutor and educational technologies more generally. Educational technology can only be as successful as the learners' ability to use it. With this in mind, we emphasize that future research needs to utilize mobile phones to address the limitations and deficits that e-learning has (Mehdipour & Zerehkafi, 2013). This will not answer all concerns of equitable access to users, but it is a major step.

Another goal for equity and accessibility requires the development of more features in AutoTutor to accommodate learners with diverse primary languages. At this point, the lessons and website design only have text and audio options in English. However, we are hoping to integrate more language resources for learners' convenience.

Applicable level: Tertiary

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