SPEECH-BASED ENGLISH SIGHT WORD READING MODEL FOR AUTISTIC CHILDREN

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ABSTRACT

Most autistic children suffer from impairments in specific cognitive processing styles, social skills, and communication skills, which affect the academic performance of those children in school. The difficulties in communication and social skills result in the lack of motivation, attention, satisfaction, and interaction in this population and these cause them deficits in learning and especially reading the text. Hence, the purpose of this study was to develop a speech-based reading model to assist Autistic children in acquiring English reading skills. In this study, the design Science Research Method (DSRM) was used, which is a six-step method for developing and evaluating the prototype. We proposed a speech-based English sight word reading model, implemented as a Desktop-based prototype and the prototype is evaluated by 15 autistic school-aged students. The findings show that the software prototype was useful to assist Autistic children in addressing the reading deficits in this population. The targeted autistic students showed significant improvement in terms of words retention after using the CBI for ten sessions. More comprehensive speech-based models for learning reading comprehension and sentence combination are considered as future work.

Keywords: Computer-Based Intervention, Reading intervention, Autistic children.

[MODEL BACAAN PERKATAAN BAHASA INGGERIS BERASASKAN PIDATO UNTUK KANAK-KANAK AUTISTIK]

ABSTRAK

Kebanyakan kanak-kanak autistik mengalami kecacatan dalam gaya pemprosesan kognitif tertentu, kemahiran sosial, dan kemahiran komunikasi yang mempengaruhi prestasi akademik anak-anak di sekolah. Kesukaran dalam komunikasi dan kemahiran sosial mengakibatkan kurangnya motivasi, perhatian, kepuasan, dan interaksi dalam populasi ini dan ini menyebabkan mereka mengalami defisit dalam pembelajaran dan terutamanya membaca teks. Oleh itu, tujuan kajian ini adalah untuk membangunkan model bacaan berasaskan teknologi menggunakan teknologi Pertuturan untuk membantu kanak-kanak Autistik dalam memperoleh kemahiran membaca bahasa Inggeris. Dalam kajian ini, reka bentuk Kaedah Penyelidikan Sains (DSRM) digunakan iaitu 6 langkah-langkah untuk membangun dan menilai prototaip. Kami telah membangunkan model bacaan bahasa Inggeris berasaskan ucapan, yang dilaksanakan sebagai sistem berasaskan Desktop prototaip dan sistem itu dinilai oleh 15 orang pelajar di sekolah autistik. Penilaian menunjukkan bahawa prototaip perisian berguna untuk menangani defisit bacaan dalam populasi ini. Pelajar autistik yang disasarkan menunjukkan peningkatan yang ketara dari segi pengekalan perkataan selepas menggunakan CBI selama 10 sesi. Model berasaskan ucapan yang lebih komprehensif untuk pembelajaran pemahaman bacaan dan gabungan ayat akan dibangunkan selepas ini.

Keywords: Intervensi berasaskan komputer, Intervensi pembacaan, kanak-kanak Autistik.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASD	:	Autism Spectrum Disorder
ADDM	:	Autism & Developmental Disabilities Monitoring
NASOM	:	National Autism Society of Malaysia
CBI	:	Computer-Based Interventions
CDC	:	Centers for Disease Control
NRP	:	National Reading Panel
TTS	:	Text To Speech
ASR	:	Automatic Speech Recognition
VHLQ	:	Visual Hybrid for Learning Quran
HER	:	Headsprout Early Reading
VHDLS	:	Visual Hybrid Development Learning System
VISO	:	Voice Input, Speech Output
SRBP	:	Speech Recognition-Based Program
SGD	:	Speech Generating Device
DSRM	:	Design Science Research Method
PC	:	Personal Computer
UI	:	User Interface
W3C	:	World Wide Web Consortium
ERM	:	English Reading Model

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

This chapter starts with the background of the research and presents the motivation for conducting this research. The problem statement, statement of purpose, research questions, and research objective is also presented. The scope, significance, and limitations of the research are described. Finally, it presents the structure of the thesis.

1.1 Research Background

Autism spectrum disorder (ASD) is a complicated developmental disorder which appears in early childhood and affects the child's communicative and interactive abilities. It is "Spectrum condition" and is a specific set of behaviors which affects the children in different ways and on different levels. No single cause for ASD is known so far, but some behaviors are known to be associated with ASD which are: Difficulties in executive functioning, poor interests, poor planning and reasoning skills, delay in learning of language, week skills in motors, deficits in eye contact, difficulties in holding a conversation, narrow and sensual sensitivities. Once more, individuals with ASD may have many of these symptoms or just some of them, or even some more besides these (McPartland, Law, and Dawson 2015). In the ADDM autism prevalence report of the Centers for Disease Control and Prevention in 2018, it is shown that the prevalence of Autism had a rise of 1 in every 59 children in the US. Previously, in 2004, this rate was 1 in 125, and in 2009, that rate was 1 in 110 children (CogSci MQ and Brock 2018). According to (Malaysian Ministry of health 2014), 1 out of 600 kids in Malaysia had Autism Spectrum Disorder (ASD). Currently, the NASOM (National Autism Society of Malaysia) statistics show that every year, around 9000 children in Malaysia are born with Autism (National Autism Society of Malaysia 2018).

It is reported in (Autism Spectrum Australia 2018) that in Australia, there are about 230 000 Autistic children, around 1 in 100 kids, and it is common for boys more than girls. Some categories of symptoms that might be seen in Autistic kids are shown in Table 1-1 below: (Autism Spectrum Australia 2018).

Table 1-1: Symptoms of ASD

No	Category	Symptoms
1	Play	o They Prefer playing with specific toys o They are interested in playing alone o Playing with things in a different way than normal children do o Their social play is very limited
2	Sensory	o Extremely patient with pain and temperature o They look at things in an outer vision o Sensitive to some usual sounds o Interested in moving items
3	Behavior	o So difficult for them to handle the changes o Abnormal motor movements o Sudden anger with no reasons o Abnormal interests and favorites
4	Social Skills	o They don’t know to share things with others o Mostly being in their own world o Less interested in other kids o Looking away while speaking to them o Rarely smile when others smile
5	Communication	o Not able to point to things by 12 months of age o abnormal speaking patterns o They listen to things selectively and will respond to specific sounds, but they ignore the voice of humans o Not able to make spontaneous sentences by two years of their age o Not able to speak at 1.5 years of age o Bad memory in words o Not able to respond to their names by one year of age

1.2 Research Motivation

In recent research on the analysis of reading abilities in children with Autism Spectrum Disorders, which was published in 2018, the authors have examined the reading performance of a total of 110 children with ASD. They have divided the participants into two groups according to their age and the result shows that reading skills in both groups were below the average range. The authors have noted that reading in autistic children needs continuous intervention and support in educational settings. The findings in this research claim that teachers may face challenges with the reading abilities in their students with ASD and it shows that more serious reading instructions are needed for students with ASD to avoid the risks of reading deficits in these children (Nally et al. 2018).

Studies have also shown that Autistic children feel better when learning with a computer-based intervention than learning from a human tutor (Picard 2009; Tartaro et al. 2014). Learners can benefit from technology-based interventions more than a human tutor in terms of availability at any time, practice, individual setting and time limitations (Boucenna et al. 2014; Chen and Waller 2012; Murray 2011; Powell 1996)

Use of speech technologies in the learning interventions can better help Autistic children in learning a language in terms of practice at self-paced speed, practicing language skills for those who find it difficult in public and solving pronunciation problems (Ehsani and Knodt 1998; Engwall, Lopes, and Leite 2017; E. L. Higgins and Raskind 2004; National Center for Technology Innovation 2018; Precoda, Halverson, and Franco 2000; Zhao 2007; Zinovjeva 2005).

1.3 Problem Statement

Most of the Autistic students do not receive sufficient instructions for reading during childhood. Therefore, they have deficits in reading performances (H. Brown, Oram-Cardy, and Johnson 2013; Nation et al. 2006). Besides, most of the teachers who are responsible for delivering reading instructions to the autistic children are not sufficiently skilled to teach reading effectively (Spector and Cavanaugh 2015).

According to Nally et al. (2018), reading abilities in children with ASD is below the average rate and these children still need better and interactive reading instructions to read proficiently. Some studies suggest that lack of motivation and confidence, due to the effects of limited instruction, failure at school tasks and poor skills also affect reading and writing skills (Iacono, Balandin, and Cupples 2001; Yoder 2001). These deficits cause them not just delay in learning but also reduces their quality of life in society. By fulfilling these deficits, Autistic children will be able to learn better (Lavie 2010).

Computer-Based interventions are needed for Early reading to address the barriers that children with ASD face when receiving reading instructions (Plavnick et al. 2016).

Difficulties in phonological processing of Autistic children have been noticed by researchers (Kluth and Chandler-Olcott 2008; Wolk, Edwards, and Brennan 2016). Also, whole-word reading is relative strength in these children (Nation et al. 2006). Some studies suggest that using sight-words for reading can help Autistic children in learning whole-word reading which will help them in better learning (Coleman et al. 2015; Paula Kluth and Darmody 2003; Torgesen et al. 1988; Yaw et al. 2011).

There are studies that address reading deficits of children with Autism Spectrum Disorder (Aljameel et al. 2018; Boucenna et al. 2014, 2014; Fletcher-Watson 2014; Knight, McKissick, and Saunders 2013), but there are no speech-based sight word reading interventions for this population, and this is a gap in the literature which will be fulfilled by the current research.

1.4 Statement of Purpose

The main purpose of this study is to help Autistic kids learn to read English sight words using a Speech-Based CBI (Computer-Based Intervention).

1.5 Research Questions

The main research question for this study is:

How do we improve English reading skills in children with Autism Spectrum Disorders (ASD) using Speech-Based Computer Interventions to read English words easily?

The above main Research Question includes the following sub-questions:

1. What are the current reading interventions for improving reading skills in Autistic children?

2. Which technologies have been used in the existent reading interventions?

3. How effective are the Computer-Based reading interventions for helping children with ASD to learn better, comparing to a human tutor?

4. Which reading instructions and design strategies are suggested for better learning of children with ASD?

5. How do we use speech recognition technology in the Computer-Based intervention to help children with ASD for better learning purposes?

6. How do we insure about the effectiveness of the CBI for the Autistic children?

1.6 Research Objectives

To answer the questions mentioned above and to achieve the purpose of the current research, we have identified and will go through below three objectives:

- To identify and analyze the existing approaches for learning English language reading.
- To develop a Speech-Based model prototype for English Sight words reading using appropriate reading instructions and speech recognition technology for Autistic kids.
- To evaluate the developed prototype by appropriate evaluation methods.

1.7 Scope of the Research

The focus of this study is to improve English Reading skills using interactive computer technologies. In this study, the research focuses on fulfilling the needs of autistic children in motivation, attention, interaction, and satisfaction. The scope of the current study is school-aged children with ASD whose age is between 8 to 14 years.

1.8 Significance of the Research

The attention, motivation, social interaction, and satisfaction difficulties of autistic children, which then cause learning deficits in them, have been studied in this research and an interactive Computer-Based intervention's model has been proposed. The proposed model in this research can be used to design interactive CBI's for this population, and it also helps software engineers to expand this project to address other learning deficits in the autistic children.

The proposed model in this research carries on two speech technologies together, which are TTS and ASR. These technologies have been widely used in the learning CBI's, and they have shown sufficient effectiveness on learning and training of children with or without Autism Spectrum Disorder.

The components in the prototype have been used according to the needs of the autistic children as they were proposed in the related studies. The prototype has been designed using the instructions by the Software developers and other researchers in the field.

The proposed model and the designed prototype in this research are too easy to be used by autistic children with minimal instruction without the mediation of a teacher or instructor.

1.9 Research Limitations

The limitation of this study is that it does not consider improving sentence construction and reading comprehension for children with ASD. However, sentence construction and reading comprehension are broad scopes in this field that can be considered as a future work for this study.

1.10 Structure of the thesis

Chapter 1: Introduction- This chapter introduces the topic of the research by providing information about the background of the research, research motivation, problem statement, statement of purpose, objectives of the research, scope and significance of the research. It also presents the research limitations and the structure of the current research.

Chapter 2: Literature Review- in this chapter, ASD, reading difficulties in Autistic children, use of CBI (Computer-Based Interventions) for Autistic children and using speech technologies in this field is discussed. This chapter also provides detailed information about the related work for addressing reading deficits and those studies that have used speech technologies. At the end of this chapter, the research method for this study is described in details.

Chapter 3: Proposed Model- in this chapter, the proposed model in the current study has been described and the design for the proposed model has been discussed.

Chapter 4: Model implementation and design- in this chapter, the proposed model has been implemented to design and develop a prototype. It also provides information about the UI design rules and recommendations, followed by screenshots of the developed prototype in this study.

Chapter 5: Evaluation- this chapter provides detailed information about the evaluation of the developed prototype. It also discusses the results of the evaluation and how it will be useful for autistic children.

Chapter 6: Conclusion- in this chapter, the conclusion and directions towards future work have been discussed.

CHAPTER 2: LITERATURE REVIEW

This chapter starts with the information about the Autism Spectrum Disorder (ASD), and it provides information about the reading disability in this population, the use of speech technology in education, and the interaction of autistic children with the CBI. At the end of this chapter, the related studies in the literature are also presented, and the research method is described.

2.1 Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder (ASD) is a developmental disorder. ASD is consist of 5 subtypes, which are: Rett Syndrome, Childhood Disintegrative Disorder, Autism, Pervasive Development Disorder—Not Otherwise Specified (PDD-NOS), and Asperger syndrome (American Psychiatric Association 2000). ASD exists from the early years of childhood or birth, and it is a disorder that disrupts important human behaviors such as imagination, the ability to communicate feelings and ideas, making relationships with others and social interaction. ASD has life-long effects on how kids learn to take care of themselves, to participate in the community, and to be social beings. ASD is originally a neurobiological disorder, which is known by developmental and behavioral features (Goldson 2001).

Autism spectrum disorder (ASD) is considered one of the neurodevelopmental problems categorized by shortages in interactions and social communication as well as repetitive and restrictive patterns of behaviors, activities, and interests (Harrington and Allen 2014). People with ASD share specific difficulties, but still, ASD will affect them by their condition in various ways. Some autistic people can live independently while some need specialist support to live their lives. They might also be sensitive to lights, sounds, colors, smells, touch, and flavors. Autism affects the following three skills in autistic people: social interaction (recognizing emotions and expression), repetitive behaviors (adaptation to the environment) and communication (non-verbal and verbal language) (National Autistic Society 2015).

Autistic children's behaviors are different from each other: one of them might be bright, engaged, and very verbal, but the other might be intellectually challenged and non-verbal (Whalon and Hart 2011). It is suggested by some studies that ASD can be genetic (Miles 2011; Wiggins et al. 2015). The occurrence of ASD is at least 65 per 10,000 people in a community, and probably 110 per 10,000 Boys might be affected more than the girls (El Zein et al. 2014). Centers for Disease Control and Prevention (CDC) has recently published that autism continues to increase, as the number of affected children is 1 in 68 children. The number of boys is more than the number of girls at a ratio of 4:1, this means 1:42 boys and 1:189 girls (Baio 2014).

ASD's symptoms might appear within the first three years of childhood and the effects of ASD might occur later in their life (Kanner 1943). In (Fombonne 2005), it is mentioned that the number of children identified with ASD is increasing, and (Marks et al. 2003) noted that most of the teachers are getting familiar with autistic children. According to the 1997 Educational Act for individuals with disabilities, schools needed to provide access to general education curricula for children with disabilities. Autistic students are increasingly engaged in academic curricula and are placed in common classrooms (Dunlap and Worcester 2001).

Recent studies from the United Kingdom and the United States show that the average costs of life for children with ASD is about ($1.4 million−$2.4 million in 2011), not including hidden expenses of families (Buescher et al. 2014).

The current form of treatment for autism is educating children and educating parents and teachers. Therefore, education is known as the best way of seeking skills or knowledge-not only including academic learning, but also communication, socialization, language, behavior problems, and adaptive skills to help autistic children to develop personal responsibility and independence. Education is consisting of the services that help the acquisition of knowledge and skills which are offered by private and public schools and other private and public service providers. Children with autism are at a high risk of impairments; therefore, planning for education must fulfill both the needs associated with ASD and associated with other disabilities (Goldson 2001).

2.2 Reading disability in Autistic children

Impairments in specific cognitive processing styles, social skills, and communication can affect the academic performance of students with ASD. A difference is seen between the predicted skill level of students on intellectual functioning and their actual success in basic number skills, reading, and spelling (Cronin 2014).

The ability to read proficiently is known as one of the most important outcomes in children's education (Anderson et al. 1988). For children with ASD to be independent in adulthood, it is required for them to have abilities further than communication and social skills, especially reading skills. Reading is an essential skill, that can increase learning chances, future employment, general quality of life, and adaptive living skills (Grigorenko, Klin, and Volkmar 2003; Lyon 2001).

The authors in (Nation et al. 2006) have tested reading skills (e.g., text comprehension, word recognition, text reading accuracy, and non-word decoding) in children with ASD (containing 16 children with autism, 12 with Asperger syndrome and 13 with atypical autism). The result of that test specified that a large number of those children displayed deficiencies in the comprehension of the text, vocabulary, and oral language (Nation et al. 2006).

To read a sentence, several skills are required, such as recognizing each letter, group of letters, and recognition of the word (Nation et al. 2006). In the first years of school, children usually learn to recognize sight words; they need to read and understand simple sentences (Kittel 2013). Later on, reading becomes more complicated for them, concentrating on grammatical points and growing vocabulary (Nally et al. 2018). Studies have shown that students with autism spectrum disorder (ASD) face difficulties with literacy skills (e.g., reading, writing, …) (O'Conner and Hermelin 1994; O'Connor and Klein 2004).

An appropriate time for developing the reading skills is the first years of childhood (Neuman, Copple, and Sue 2000). Current studies show that children with ASD have deficiencies in pre-reading skills even before starting school (Ricketts 2011; Westerveld et al. 2016).

The National Reading Panel (NRP) is a research organization in which there are researchers from different areas, such as psychology, higher education, and reading education; this organization aims to examine the effectiveness of different strategies on how to read (Cunningham 2001). They have recognized five important components of reading, which are oral reading fluency, phonemic awareness, text comprehension instruction, vocabulary instruction, and phonics as well as for each of the five components. The NRP has recommended different approaches related to each of the components. Association methods, capacity methods, indirect instruction, multimedia instruction, and explicit instruction are the strategies for vocabulary instruction while question answering, graphic and semantic organizers, cooperative learning, question generation, story structure, summarization, and comprehension monitoring are the strategies for text comprehension instruction (Khowaja and Salim 2013).

2.3 Technology and Autistic children

Several studies have conveyed that individuals with ASD can deal with computers and technology-based interventions better than with humans (Banire, Jomhari, and Ahmad 2015; Picard 2009; Tartaro et al. 2014). People with autism prefer computer applications due to the routine and repetitive behaviors in the applications' environments (Murray 2011). Tutors in the Virtual environment have been effective to help children with ASD, who are weak in social interactions (Parsons and Cobb 2011).

Traditional ways of teaching autistic children by human tutors are challenging for them and cannot fulfill the needs of each autistic kid, whereas the tutors in a virtual environment can meet their needs. The reason is that children with ASD don't show comfortableness while looking at faces, but tutors in the virtual environment usually look like a cartoon and children with ASD are comfortable with them. At the same time, in a virtual environment, it is possible to arrange the contents of the session according to the children's understanding level. It is suggested by some studies that children with ASD gain more information when they are taught by tutors in virtual environment comparing to those who are taught by human tutors (Grynszpan, Martin, and Nadel 2008).

Children with ASD can benefit from Virtual tutors much more than human tutors, for example, teaching and practice with virtual tutors are not limited but human tutors might face pressure and tiredness after a limited number of tasks or practices (Massaro 2004). Due to the abnormal sleep patterns in children with ASD, virtual tutors can further benefit them by being available at any time, but human tutors will need some rest. At the same time, human tutors need a proper schedule to work with, but virtual tutors are suitable with any schedule and in any number of hours for practice (Limoges et al. 2005). An effective method for teaching children with learning disabilities is the use of computer and technology-based learning systems (Limoges et al. 2005).

An interactive learning environment is provided by the computer and technology-based methods for children (Lavie 2010). It is suggested by researchers to use computer-based Interventions as a support tool for teaching kids with autism and those interventions are broadly used in the special education area (K. Higgins and Boone 1996; Powell 1996). Autistic kids usually need more one-to-one guidance for better performance. Computer-based Interventions help them work independently with an unlimited number of practices, which will increase learning possibilities in kids and will improve their social behavior and attention span (Panyan 1984).

2.4 Speech Technology in education

Speech technology is one of the new technologies that can enable the machines to get the human voice as an input and reply to it by oral language as an output. This ability of the speech technology has made it more important in human-computer interaction and it has attracted the attention of people to use it in educating the students with disabilities. Therefore, there are two categories for speech technology, which are Text-To-Speech (TTS) and Automatic Speech Recognition (ASR) (Zhao 2007). Speech technology is not only an important element of Computer-Based language learning programs, but also it is ready to be used in learning second languages. Although the speech technologies have some limitations, still these technologies have been used and designed in ways that work for learning a foreign language successfully (Ehsani and Knodt 1998).

Speech-Based learning systems hold several benefits for foreign language learners. Speech-based systems allow learners to practice at a self-paced speed, to practice in an unlimited number of times, and also these systems can address the individual problems of the language learners. These systems also help those learners who cannot practice speaking in public, and it will improve their speaking skills (Zinovjeva 2005).

The recent advancements in the field of technology have changed the interaction methods between learners and educators. By using these new technology-based self-learning tools, learners do not interact with a human teacher enough and they just try to learn from a technology-based tutor, which is an example of using speech technologies. The integration of video, audio, animation, and text has helped in creating interactive learning environments which are enough to replace the traditional ways of teaching and learning. Use of these technologies in the field of foreign language learning was even more than the other fields of education (Ehsani and Knodt 1998).

The use of speech technology to support people with disabilities were recognized a long time ago. Most of the researchers and organizations have tried to help individuals with disabilities by using the speech technologies in 2 ways: helping in learning and helping with performance. To help people with disabilities in better performance, the researchers have focused on helping people with disabilities to control devices that cannot be controlled otherwise and to gain access to the otherwise inaccessible contents (Zhao 2007). The use of speech technology is very useful for teaching lexical stress, intonation, the pronunciation of words and phones, assessing the quality of pronunciation, improving conversational and communication skills and improving comprehension of the text (Zinovjeva 2005).

2.4.1 TTS (Text-To-Speech) in Education

The TTS or Speech synthesis is one of the speech technologies that transforms a printed text onto electronically readable, synthesized text. Text-To-Speech allows any type of text to be accessed and it is different than audio-texts (Anderson-Inman and Horney 2007; Rose and Meyer 2000).

TTS does the opposite of ASR (Automatic Speech Recognition). TTS converts a text into speech and it helps the learner with a reading disability to read the text from the screen. TTS is available with computer software programs that are called speech synthesizers (Parr 2013; Zhao 2007). One of the first speech technologies that has been applied earlier and has been used to help individuals in accessing the printed text is speech synthesis. Kurzweil Reading Machine was the world's first text to speech machine which was built and used in 1976. Nowadays, speech synthesis technology or TTS has been widely used in different fields and especially in transforming the written text, emails, and websites to spoken language. This helps people with literal and physical disabilities to access to the contents of the web and other printed text (Zhao 2007).

Rebecca Hincks, in his research, discussed the use of speech synthesis as an interactive tool for teaching English to young adults who speak Swedish as their first language. According to Hincks, speech synthesis was successfully used to teach learners English vowel quality. He states that the potential of the speech technologies in computer-assisted learning programs lies in the use of speech synthesis (Hincks 2005).

2.4.2 ASR (Automatic Speech Recognition)

In this research, we have used VB.Net programming language to develop a prototype of the proposed model. Therefore, we have used the ASR (Automatic Speech Recognition) provided by Microsoft Corporation for .Net applications.

2.4.2.1 About ASR (Automatic Speech Recognition)

ASR is the speech recognition system of Microsoft Corporation and previously it was used with other different names, such as Sphinx I/II, WHISPER, SAPI and finally after more advancement and development, it is ASR (Xiong et al. 2018; Xuedong Huang et al. 2002).

Speech recognition was a challenge for years, but a study group by Allen Newell in 1971 recommended the usage of many more resources of knowledge can bear the problem of speech recognition (B. X. Huang, Baker, and Reddy 2014).

The Defense Advanced Research Project Agency (DAPRA) was sponsoring some research projects. One of these research projects was the Speech Understanding Research (SUR) project, which was responsible for research on Speech recognition. Raj Reddy, professor at Carnegie Mellon University, was also leading a group of researchers in this project by 1976. This group has developed several speech recognition systems: Harpy, Dragon, Hearsay, and Sphinx I/II. Harpy was the first system that introduced the Beam Search, which is widely used for best matches while searching. The Dragon was the first system that had the capability of modeling speech as a hidden stochastic process. Hearsay introduced continuous speech recognition for the first time. Sphinx I, was the first speaker-independent speech recognition system which was developed in 1987. Sphinx II was the advanced version of Sphinx I and could achieve the highest accuracy in recognition in a speech benchmark evaluation in 1992 (Deng et al. 2013; B. X. Huang, Baker, and Reddy 2014; Xuedong Huang et al. 2002).

Microsoft Windows 95 was the first operating system which was shipping Microsoft SAPI to help application developers in creating speech-based applications in 1995. Later in 1999, to support telephony IVR, the VoiceXML forum was created, and in 2001, Bill Gates demonstrated MiPad at CES as a prototype (X. Huang et al. 2001).

The huge amount of speech and text data on the internet helped the speech recognition researchers to develop and improve speech recognition technologies over the past decades. The availability of huge data on the internet around the world enabled the researchers in creating large corpora for speech training, development, and evaluation. Over the years, these corpora have been created by different languages and they were efficient in creating a large number of speech recognition systems with higher and more qualified capabilities (Bahl et al. 1986).

There have been several challenges for speech recognition technologies over the last four decades, but with the advancement of the computer systems, processors, memories, and the internet, most of those problems have been resolved. In the 80's, we could perform speech recognition just on a limited number of vocabularies and the computers at that time were also not so advanced. The fasted computer system for speech research which was being used in 1976, was a system with 4MB of memory. The systems nowadays are a million times more powerful in processing and storage of data. The new systems can collect speech data with a size of millions of hours from millions of people and process it (B. X. Huang, Baker, and Reddy 2014; X. Huang et al. 2001).

One of the earliest speech recognition systems used by Microsoft was SPHINX which was being used before SPHINX-II and WHISPER (Deng et al. 2013; Xiong et al. 2018; Xuedong Huang et al. 2002).

While designing SPHINX, it is tried to overcome small vocabulary, isolated words, and speaker-dependence constraints. The discrete Hidden Markov Models (HMM) was employed to the SPHINX, and knowledge was added to these models to help SPHINX deal with speaker independence. At the same time, two new speech units of function-word dependent phone models were introduced, and these helped SPHINX to achieve speaker-independent work recognition accuracies of 96, 94 and 71 percent on the 997-word DARPA resource management task. For the speech data, Texas Instruments supplied Carnegie Mellon with a large speech database called the TIRM database. This database contains 80 speakers for training purposes, 40 speakers for development test and 40 speakers for evaluation. 35 out of these 120 speakers were female, and the rest 80 speakers were male. Each of the speakers was reading 40 sentences and SPHINX received a collection of 4200 training sentences (Lee, Hon, and Reddy 1990).

Training of the words has been done using hand-labeled and hand-segmented from the words database. An iteration on the hand-labeled phone segments was run and for each phone, a model was produced. Then, the algorithm was applied to the TIRM 4200 training sentences and sentence models were created using word models which were created from phone models. For evaluation of the SPHINX system, the recognition accuracy of the system was evaluated with 15 speakers with ten sentences each and the results has shown high recognition accuracy (Lee, Hon, and Reddy 1990).

After SPHINX, SPHINX-II was used by Microsoft and later on Microsoft SAPI was introduced in Microsoft Windows 95 for the first time in 1995. Recently, Microsoft is using ASR (Automatic Speech Recognition) as the speech recognition system to its operating systems. Improvements have been brought to the speech recognition systems of Microsoft over the years and the researchers in Microsoft Research always work for the advancement of the speech systems (Deng et al. 2013; X. Huang et al. 2001; Xiong et al. 2018).

In (Deng et al. 2013), the deep learning techniques used for improving speech recognition systems have been discussed. This paper shows that between 2009 and 2013, some of the deep learning techniques such as dialogue state estimation, speech understanding, language modeling, acoustic modeling, and feature extraction have been used to improve Microsoft Speech Recognition systems (Deng et al. 2013).

In (Xiong et al. 2018), the 2017 conversational speech recognition system of Microsoft has been described. The authors in this paper have discussed the recent improvements in the 2016 speech recognition system and recent developments in language modeling and neural-network-based acoustic modeling. The system adds a character-based and dialog session language models and also a CNN-BLSTM acoustic model to the models that were previously used in the system.

2.4.2.2 ASR (Automatic Speech Recognition) in Education

ASR is also one of the speech technologies that works the opposite of TTS. It allows the users to talk to the computer or other ASR-Based devices. Their speech or spoken language will then be recognized by the ASR systems, and it is changed into text for further uses (Zhao 2007).

ASR makes it possible to have a conversation with a computer in a dialogue system (Zinovjeva 2005). ASR provides an optimal solution to those who have pronunciation difficulties and it can be used as a useful pronunciation learning tool (Neri, Cucchiarini, and Strik 2001).

Speech recognition is generally used in 2 modes. The first mode of using ASR is the dictation mode. In this mode, ASR provides the opportunity to the user to enter data by talking to a computer or other ASR-based device. The user in this mode dictates to the system using ASR what the user wants to write, and the device recognizes the voice and converts the recognized voice into text. ASR engines are speaker-dependent. That means that the accuracy of the recognition depends upon the user's accent and speaking mode (Zhao 2007).

The second mode is the control or the command mode. In this mode, the ASR-based system lets the user control the computer or other devices. The user can use their voice to print or save files, close a program, etc. In command mode, the number of commands (list of already recognized commands or recognized words) might be limited, and this helps with better performance and accuracy. Nowadays, the available speech recognition technology has an accuracy of above 90%, and both the operating systems, Windows, and Macintosh have included ASR in their recent versions. A large number of ASR-based computer programs are available for free or at a low cost. Speech technology is widely used in different areas and some available Speech software on the market are as below: FreeSpeech98, Voice Xpress, Dragon, and ViaVoice (Zhao 2007).

2.5 Related Work

Our review of the related work includes two groups of related work. In the first group of a related word, we will review the researches that have designed a CBI to address the reading deficits of the children with ASD. In the second stage, we will review the studies that have used speech technologies for addressing literacy difficulties of individuals.

2.5.1 Reading-related CBI for children with ASD

There is a large number of studies that have either proposed or designed computer-based interventions for children with ASD in different areas for treatment or teaching purposes. These studies address Improving the social and communication skills, improving job and interview skills, improving face and emotion recognition, self-injuries, behavioral learnings, attention, education and literacy (Aljameel et al. 2018; Banire et al. 2017; Boucenna et al. 2014, 2014; Fletcher-Watson 2014; Khowaja and Salim 2013; Knight, McKissick, and Saunders 2013).

We have identified four studies that address reading deficits in children with ASD and have been published between 2011 to 2018. These four studies have addressed text reading and phonetic symbol identification. The basic details about the studies are listed in Table 2-1.

In the first study (Banire, Jomhari, and Ahmad 2015) included in this review, the authors have proposed a visual hybrid development learning system which will help developers to develop appropriate learning tools for Autistic children. In this study, a Visual Hybrid for Learning Quran (VHLQ) prototype has been developed to teach verses of the Holy Quran to children with ASD. This prototype was evaluated with 11 autistic children, and at the end, they showed improvement in reading the Holy Quran verses.

In the 2nd study (Plavnick et al. 2016), the authors have examined the effectiveness of the Headsprout Early Reading (HER) program for children with Autism Spectrum Disorder. They have identified five students with ASD and included just 3 of them in their experiment according to their inclusion criteria. As presented in the result of the test, they have noted improvements in the performance of the three students in text reading.

Table 2-1: Details of the four reading-related work

No	Authors	Title	Year	Area of focus
1	Bilikis Banire, Nazean Jomhari & Rodina Ahmad	Visual Hybrid Development Learning System (VHDLS) Framework for Children with Autism	2015	Reading verses of the Holy Quran
2	Joshua B. Plavnick, Julie L. Thompson, Carol Sue Englert, Troy Mariage & Katie Johnson	Mediating Access to Headsprout Early Reading for Children with Autism Spectrum Disorder	2016	Reading text
3	Chien-Hsing Chou, Yung-Long Chu, and Hui-Ju Chen	A Mandarin Phonetic Symbol Communication Aid Developed on Tablet Computers for Children with High-functioning Autism	2017	Mandarin Phonetic Symbols identification
4	Jared S. Yaw, Christopher Skinner, John Parkhurst, Cora Taylor, Joshua Booher, and Karen Chambers	Extending Research on a Computer-Based Sight-Word Reading Intervention to a Student with Autism	2011	Sight-Word reading using recorded voice for pronouncing the words

The 3rd study in this review (Chou, Chu, and Chen 2017), is a Mandarin Phonetic symbols identification tool which is called Zhuyin communication board. It is a computer tablet-based application which is available on the iTunes app store and has been developed to help autistic children to learn phonetic symbols of Mandarin. For testing this intervention, two autistic children, and a child psychiatrist participated and evaluated the intervention. Besides, the authors had provided them with a questionnaire and by getting feedback from the participants, they have reported that the participants were satisfied with the system. In this system, they have also used speech technologies and the user can have speech feedback from the system. The contents of this system are presented in Chinese Mandarin language and users do not need to have previous knowledge of English for using this system.

And the last paper in this review (Yaw et al. 2011), is a Computer-Based Sight-Word Reading Intervention (CBSWRI) which is used to teach sight word reading to a 6th-grade student with autism. In this paper, the authors have developed a computer-based intervention using Microsoft PowerPoint. They have used three Dolch words lists in three phases to teach a 6th-grade student how to read those words. They have recorded the voice of one of their colleagues as a Text-To-Speech for pronouncing the words. The words are displayed to the student one word at a time for 2 seconds, and the student needs to read the word correctly before it disappears after 2 seconds. In the end, they have noticed improvements in the child's performance in reading, and the student has learned 25 words in 16 sessions. This study uses Microsoft PowerPoint, which has limitations of usage, and it does not support Text-To-Speech. A separate application equipped with Text-To-Speech will be required for pronouncing the words to the students to learn how to read a word.

2.5.2 Speech-Based Computer Interventions

A considerable number of CBI (Computer-Based Intervention) and Mobile-Based learning software have been developed to help children with learning or physical disabilities by using speech technologies. These interventions have used either TTS (Text-To-Speech) or ASR (Automatic Speech Recognition) as a tool for interaction between the learner and the intervention.

In this study, we will describe some of these interventions that have been proposed or have been developed to address learning and literacy deficits in children with either physical disabilities or learning disabilities or the difficulties in children with Autism Spectrum Disorder. Table 2-2 shows the basic details of the studies included in this review.

Table 2-2: Details of the Speech-Based related work

No	Authors	Title	Year	Area of focus
1	(Bouck, Meyer, and Joshi 2013)	Accessing Algebra via MathSpeak™: Understanding the Potential and Pitfalls for Students with Visual Impairments	2013	Algebraic expressions
2	(Garrett et al. 2011)	Using Speech Recognition Software to Increase Writing Fluency for Individuals with Physical Disabilities	2011	Writing fluency, accuracy, type of word errors, and length
3	(Rosenthal et al. 1998)	Computer-Based Speech Recognition as a Replacement for Medical Transcription	1998	Transcription of the medical reports
4	(Precoda, Halverson, and Franco 2000)	Effects of Speech Recognition-based Pronunciation Feedback on Second-Language Pronunciation Ability	2000	Pronunciation

5	(Leong 1992)	Enhancing reading comprehension with text-to-speech (DECtalk) computer system	1992	Reading comprehension
6	(Bouck, Flanagan, and Joshi 2011)	Speaking Math – A Voice Input, Speech Output Calculator for Students with Visual Impairments	2011	Mathematical calculation
7	(E. L. Higgins and Raskind 2004)	Speech Recognition-based and Automaticity Programs to Help Students with Severe Reading and Spelling Problems	2004	Story reading comprehension and spelling
8	(Anwar et al. 2011)	A computer game based approach for increasing fluency in the speech of the autistic children	2011	Pronouncing the whole sentence correctly
9	(Schlosser and Blischak 2004)	Effects of Speech and Print Feedback on Spelling by Children With Autism	2004	Spelling the sentences, they hear
10	(Cassidy et al. 2016)	Expressive visual text-to-speech as an assistive technology for individuals with autism spectrum conditions	2016	Teaching different facial emotional expressions
11	(Waddington et al. 2014)	Three children with autism spectrum disorder learn to perform a three-step communication sequence using an iPad ® -based speech-generating device	2014	Teaching the communication sequence

12	(Williams, Nix, and Fairweathe r 2000)	Using Speech Recognition Technology to Enhance Literacy Instruction for Emerging Readers	2000	Storybook reading and comprehension
13	(Liu et al. 2007)	Using visual speech for training Chinese pronunciation	2007	Chinese pronunciation

In the first paper of the Speech-Based studies (Bouck, Meyer, and Joshi 2013), the authors have used supported eText player (ReadHear™) based on MathSpeak™. This is a TTS-Based program which is designed for Algebraic Expressions. The program reads the Algebraic expressions to the students, and after providing the solution, it also reads the result to the students and it helps the students learn those algebraic problems and solutions.

Authors in the second study (Garrett et al. 2011), have used Microsoft Word 2003, speech recognition software, and a computer to help physically disabled students in writing fluency. This program is designed for physically disabled students who are unable to write. The Speech Recognition Software will recognize the sentences they read and the program will write those sentences in a Microsoft Word 2003 file. The program is also able to recognize some commands from those students, e.g., save, print.

The third study in this review (Rosenthal et al. 1998), the authors have used MedSpeak™ (Continuous Speech Recognition) for Transcription of the medical reports. This is also a speech-based program based on MedSpeak™ that help the medical doctors transcripting the medical reports. The doctors need to read the medical report; the program recognizes the words and writes the report in a text page, which saves the time of the medical doctors.

In (Precoda, Halverson, and Franco 2000), the authors have used FreshTalk software (ASR-Based) for helping second language learners in pronunciation. This speech-based software helps second language learners with pronunciation feedback for improving their pronunciation abilities.

In (Leong 1992), the author has used DECtalk, which is a TTS-Based technology. This speech-based computer program helps the user in reading comprehension. The program reads the sentences to the users and wants them to solve some questions related to the topics at the end.

In (Bouck, Flanagan, and Joshi 2011), the authors have used computer-based VISO (Voice Input Speech Output) calculator based on MathSpeak™ for mathematical calculations. This speech-based program receives the mathematical problems as a voice input from the users, solves them and presents them the solution in speech-based format.

In (E. L. Higgins and Raskind 2004), the authors have developed a Speech Recognition-based and Automaticity Program using Microsoft PowerPoint(r) 97 to help students with reading spelling problems. In this program, a story will be displayed to the students on a Microsoft Powerpoint slide and the students need to read the story. The Speech recognition software will recognize the voice of the students, and the instructor will provide them with feedback.

In (Anwar et al. 2011), the authors have developed a computer-based game to help autistic children with speech difficulties. In this program, they have used Java socket-based network, MySQL, and ASR. This program helps autistic students with a strong vocabulary in reading the whole sentence correctly.

The authors in (Schlosser and Blischak 2004), have used LightWRITER-SL35 SGD, and Picture Communication Symbols (PCS 1992) to develop a TTS-based program for helping autistic children in spelling. This program is designed for autistic children and helps them in improving their spelling abilities. The program reads some sentences to the users, and the users then need to spell the sentences they hear.

In (Cassidy et al. 2016), the authors have developed a program for teaching different facial emotional expressions to autistic children. This program is TTS-Based program which is designed using XpressiveTalk, which is a Human face avatar.

The authors in (Waddington et al. 2014) have developed an iPad-based application using "Proloquo2GoTM SGD" technology. This application was developed for three autistic children to teach them communication sequences.

In (Williams, Nix, and Fairweather 2000), the authors have developed a Speech-recognition-based application which looks like a storybook. The users need to read the story aloud, and the application can recognize their voice and provides them with feedback. In this application developed in this study is named "Watch Me! Read", and it looks like an opened book.

Finally, in (Liu et al. 2007), the authors have developed a TTS-Based application using "Baldi", which is a "talking head". This application is also a speech-based application which is used for training Chinese pronunciation.

From reviewing the literature, we can conclude that:

1. TTS and ASR have been widely used for teaching and learning purposes, and most of the studies have noticed improvements in their audiences. (Bouck, Meyer, and Joshi 2013; E. L. Higgins and Raskind 2004; Leong 1992; Rosenthal et al. 1998; Schlosser and Blischak 2004; Waddington et al. 2014).

2. TTS and ASR are better alternatives to human tutors. (Banire, Jomhari, and Ahmad 2015; Bouck, Flanagan, and Joshi 2011; Chou, Chu, and Chen 2017; Plavnick et al. 2016; Precoda, Halverson, and Franco 2000)
3. Children with autism have shown interest in the speech-based programs and they have performed better when using the speech-based CBI. (Anwar et al. 2011; Bernard-opitz, Sriram, and Nakhoda-sapuan 2001; Boucenna et al. 2014; Bouck, Flanagan, and Joshi 2011; Cassidy et al. 2016; Chou, Chu, and Chen 2017; Garrett et al. 2011; Liu et al. 2007; Precoda, Halverson, and Franco 2000; Williams, Nix, and Fairweather 2000)
4. Finally, there are very few studies that address reading deficits of autistic children (Abidoğlu, Ertuğruloğlu, and Büyükeğilmez 2017; Aljameel et al. 2018; Aresti-Bartolome and Garcia-Zapirain 2014; Khowaja and Salim 2013; Salim et al. 2016).

2.6 Research methodology

As long as this study deals with the development and evaluation of a prototype, we use the Design Science Research Method (DSRM), which has been suggested in (Peffers et al. 2007). This method includes the following six steps: Identifying the problem and motivation, defining objectives of a solution, designing and development, demonstration, evaluation, and communication. DSRM is a systematic methodology for developing and evaluating an artifact to come out with a solution for a specific problem. Therefore, this method is used in this study with a focus on a systematic literature review for identifying the problem, developing an artifact (English Sight-Word Reading Model prototype in this research), demonstrating the use of it, evaluate it to ensure about the effectiveness and communicating the results with the audiences. Figure 1 below shows the process model for DSRM.

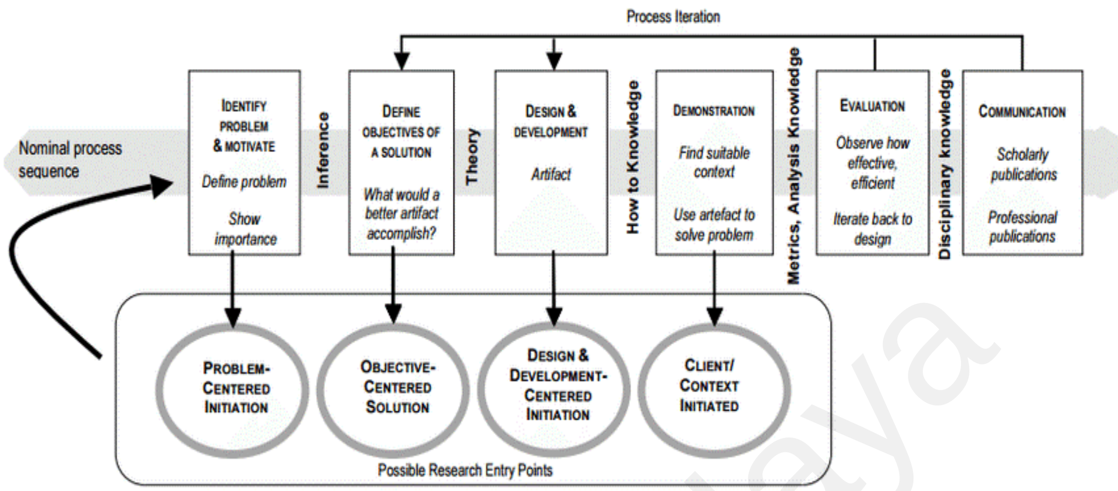

Figure 1: DSRM Model

The processes of DSRM, the relations between DSRM steps and this research's objectives, and how the RQs have been answered are shown in figure 2 and figure 3 below.

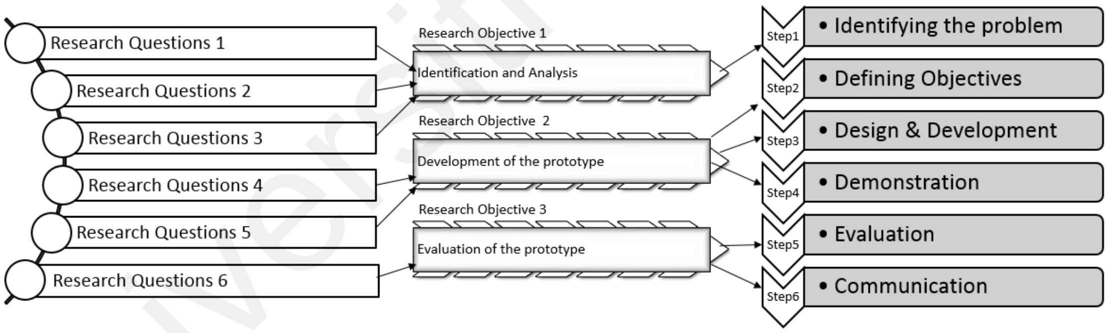

Figure 2: DSRM implementation in this research

Figure 2 shows how DSRM is used in this research to perform the research objectives and answer the research questions in this research while figure 3 shows the relationship between DSRM model's steps and the related activities in the current research. The detailed description of the six steps of DSRM is presented below.

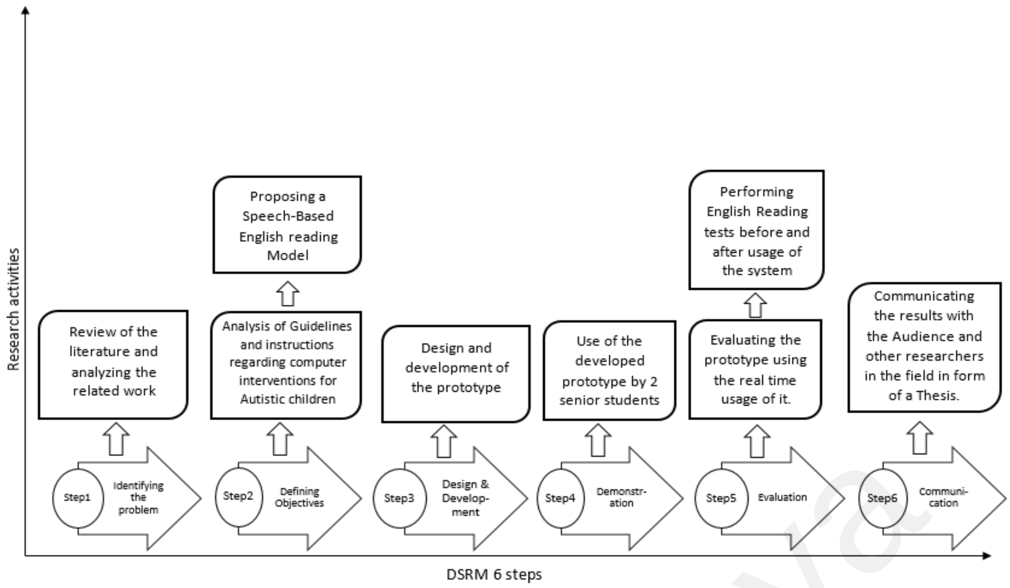

Figure 3: Relationship of the DSRM Model with the activities of this research

2.6.1 Problem identification and motivation

This step aims to understand the problem with the literature to be addressed during the research (Peffers et al. 2007). In this research, for identifying the problem, a systematic literature review of the strategies and CBIs being used to address reading deficits in children with ASD has been performed. The problem being addressed in this study is the English reading deficits, caused by luck of attention and interaction in children with Autism Spectrum Disorder. We have searched Google Scholar, PubMed, ScienceDirect, Web of Science, and Springer websites for finding related publications in the literature. At first, we could find 6540 journal articles related to education and autistic children, but we set some criteria to exclude some of the non-related articles. Our inclusion criteria were:

- Journal articles should address the literacy deficits of Autistic children (1850 articles were excluded).
- Journal articles should address young autistic children (2344 articles were excluded).

- Journal articles should be Technology-Based Interventions (1230 articles were excluded).
- Journal articles should be speech-based interventions (752 articles were excluded).

Finally, after applying the criteria, we could find 364 journal articles that were closely related to the title of this research. After reading the journal articles and comparing them to the goal of our research, we could find 16 mostly related articles and included them in our literature review. Figure 4 shows the flowchart of searching and filtering the research papers for the literature review.

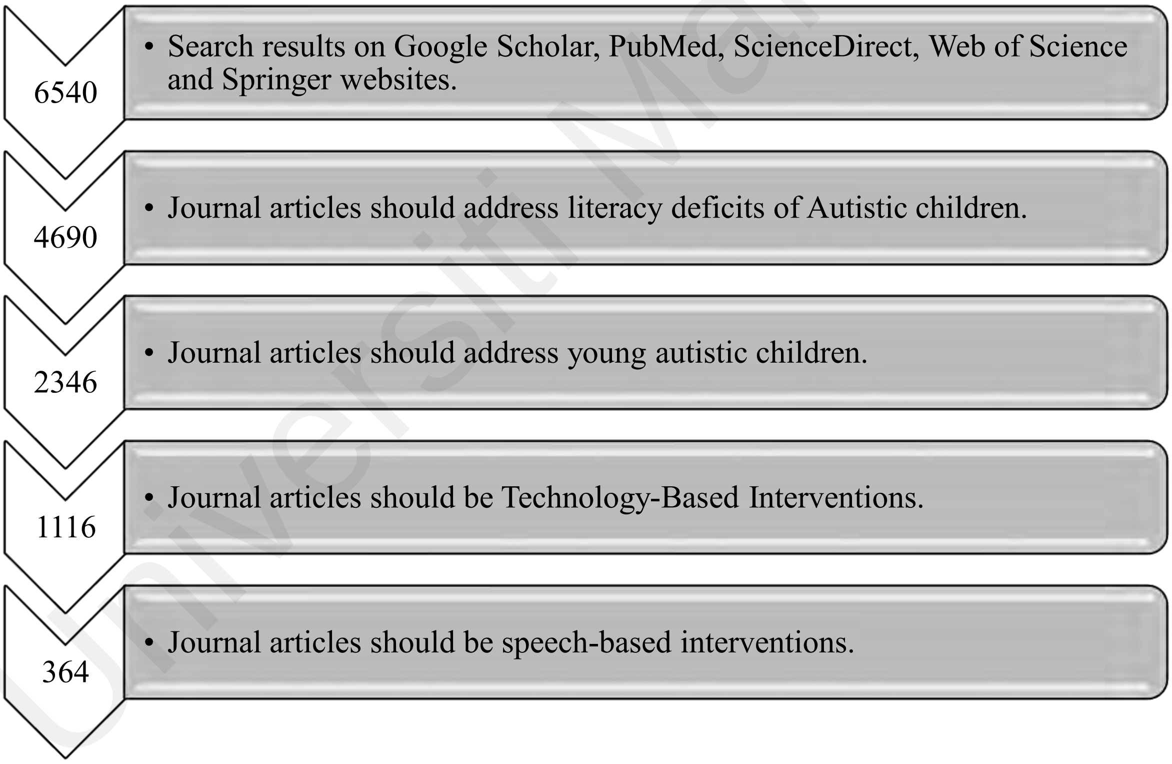

Figure 4: Flowchart of searching and filtering the related work

After reviewing the literature and analyzing the results of the studies, the following problems were identified and will be addressed by the current research.

- Most of the Autistic students do not receive sufficient instructions for reading during childhood. Therefore, they have deficits in reading performances (H. Brown, Oram-Cardy, and Johnson 2013; Nation et al. 2006). Besides, most of the teachers who are responsible for delivering reading instructions to the autistic children are not sufficiently skilled to teach reading effectively (Spector and Cavanaugh 2015).
- According to Nally et al. (2018), reading abilities in children with ASD is below the average rate and these children still need better and interactive reading instructions to read proficiently. Some studies suggest that lack of motivation and confidence, due to the effects of limited instruction, failure at school tasks and poor skills also affect reading and writing skills (Iacono, Balandin, and Cupples 2001; Yoder 2001). These deficits cause them not just delay in learning but also reduces their quality of life in society. By fulfilling these deficits, Autistic children will be able to learn better (Lavie 2010).
- More Computer-Based interventions are needed for Early reading to address the barriers that children with ASD face when receiving reading instructions (Plavnick et al. 2016).
- Difficulties in phonological processing of Autistic children have been noticed by researchers (Kluth and Chandler-Olcott 2008; Wolk, Edwards, and Brennan 2016). Also, whole-word reading is relative strength in these children (Nation et al. 2006). Some studies suggest that using sight-words for reading can help Autistic children in learning whole-word reading which will help them in better learning (Coleman et al. 2015; Paula Kluth and Darmody 2003; Torgesen et al. 1988; Yaw et al. 2011).

- There are studies that address reading deficits of children with Autism Spectrum Disorder (Aljameel et al. 2018; Boucenna et al. 2014, 2014; Fletcher-Watson 2014; Knight, McKissick, and Saunders 2013), but there are no speech-based sight word reading interventions for this population, and this is a gap in the literature which will be fulfilled by the current research.

At the end of this step and reviewing the literature, our first research objective has been achieved, and the first 3 Research Questions have been answered.

2.6.2 The objective of the solution

This step aims to find solutions for the identified problems in step 1. In this study, the objective is to find new and effective reading instruction and design strategies and apply them to developing an interactive learning model for children with ASD.

The proposed model in this study will contain the components which are recommended by other researchers in this field.

To address the first identified problem in this study, we need to have a computer-based intervention while students with ASD perform better when they deal with a computer-based tutor compared to a human tutor (Banire, Jomhari, and Ahmad 2015; Picard 2009; Tartaro et al. 2014) because they don't receive sufficient instructions for reading during childhood from their reading instructors (H. Brown, Oram-Cardy, and Johnson 2013; Nation et al. 2006).

The second identified problem is that Autistic children need better and interactive reading instructions to read proficiently and some studies suggest that lack of motivation and confidence, due to the effects of limited instruction, failure at school tasks and poor skills also affect reading and writing skills in these children (Iacono, Balandin, and Cupples 2001; Yoder 2001). So, to address this problem, we need to have some speech systems in our model so that children can interact with the computer-based intervention and also some graphics so that they get enough motivation to work with the intervention and learn reading.

As long as Autistic children have difficulties in phonological processing (Kluth and Chandler-Olcott 2008; Wolk, Edwards, and Brennan 2016), as well as whole-word reading is relative strength in these children (Nation et al. 2006), some studies suggest that using sight-words for reading can help Autistic children in learning whole-word reading which will help them in better learning (Coleman et al. 2015; Paula Kluth and Darmody 2003; Torgesen et al. 1988; Yaw et al. 2011). So, we will use English Sight words in our proposed model so that Autistic children can read and memorize these words easily.

At the end of this step, Research Question 4 of this study is answered. Figure 5 shows how the proposed solutions address the identified problems.

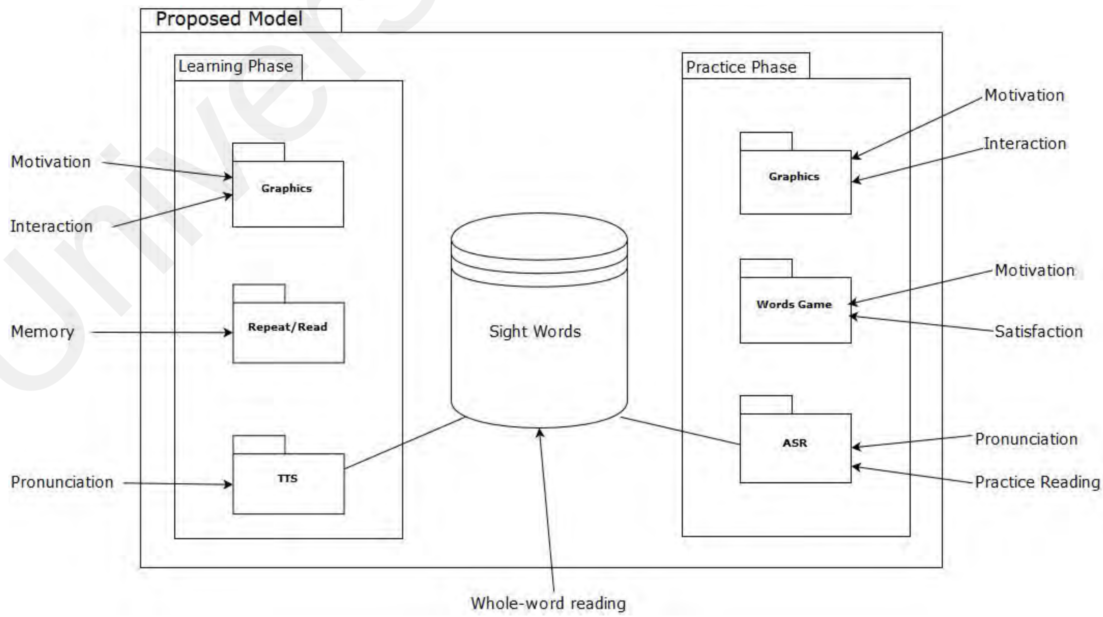

Figure 5: The identified problems and the proposed solutions

2.6.3 Design and Development

The purpose of this step is to use the findings in step 2 for developing and designing an artifact. In this study, using the objectives in step 2, a prototype will be developed in the form of a Microsoft Windows Desktop application with an interactive environment and equipped with TTS (Text-To-Speech) and ASR (Automatic Speech Recognition). This application is consisting of two phases, which are learning phase and practice phase for the English reading. Following the objectives in step 2 and getting the idea from the review of the literature, we came out with a framework for our prototype to be developed accordingly. Figure 6 below shows the framework for the proposed model's prototype. At the end of this step, the 4th and 5th questions out of our 6 Research Questions are answered.

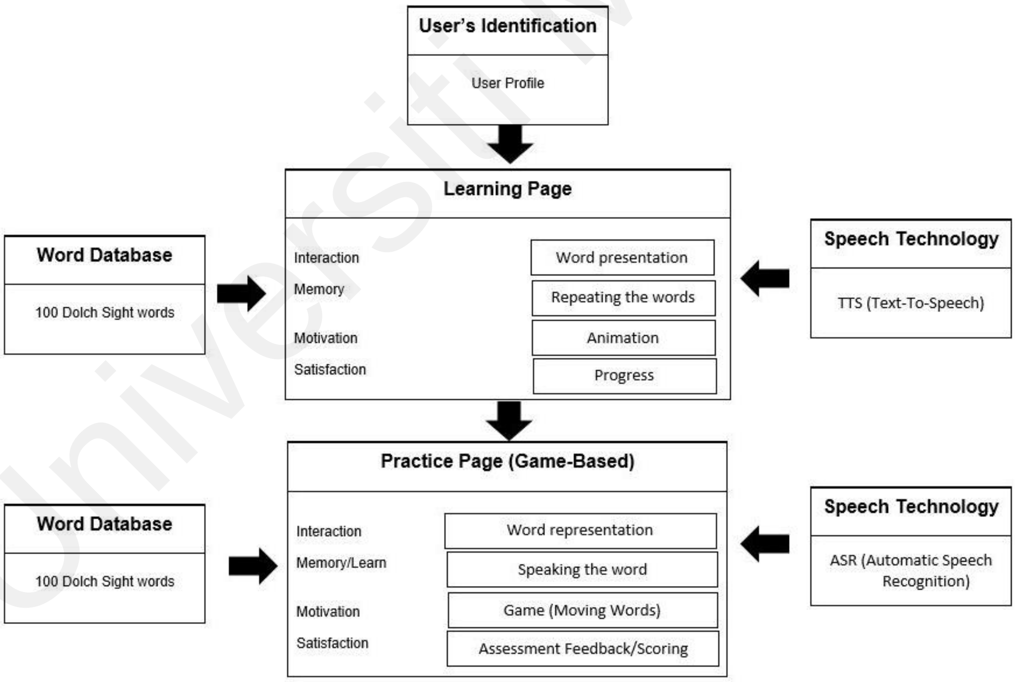

Figure 6: The research framework for this study

2.6.3.1 Design Guidelines and Recommendations

People with Autism Spectrum Disorder have different preferences due to their different levels of disorder. One of the important components in the CBI that should be considered when designing the CBI for people with ASD is the UI (User Interface) to be designed properly (Pavlov 2014). For designing a CBI to the people with ASD, the developers need to have feedback from the experts in the field, as well as form the real users of the CBI which are individuals with ASD (Bölte et al. 2010).

A basic guideline and methodology on how to prepare documents for people with learning disabilities was published by Department of Health (UK), and it presents the following rules (We have chosen just 3 Rules which were related to reading the Words) for preparing documents on the user interface:

Rule 1: Words being used on a user interface should be easy to understand.

Rule 2: Words should be clearly written or printed.

Rule 3: Words have to be big enough to be seen easily. (Department of Health (UK) 2009)

The authors in (Freyhoff et al. 1998) also created a methodology for preparing documents for the people with learning disabilities, and there are some extra recommendations suggested in this research paper as following:

- A picture should not be used as a background for the text as it makes reading the word difficult.
- Each word should be in a separate line.
- Too many typefaces should not be used.
- The text size should be as large as possible.

- Words should not be emphasized using Italic or Block capitals. For emphasizing, it is better to use Bold or underline styles.

- Illustrations used on the UI should be in a sharp focus.

- Inverted printing of the words should not be used. Using Dark words in a light background is easiest to read.

- For boxes, pictures, and frames, it is recommended to use colors.

- Long words should not be hyphenated. All letters in a word should be together. (Freyhoff et al. 1998)

One of the methods that UI designers and Application developers rely on, is using multimedia tools in an application for people with reading difficulties (Lin et al. 2013; Smith, Spooner, and Wood 2013) but it should be noted that the use of rich multimedia tools will result in weak performance of the application. In (Grynszpan, Martin, and Nadel 2008), the authors carried out their research on ten neuro-typical children and 10 Autistic children. These children showed lower performance with the richer multimedia interfaces (Pavlov 2014). It is recommended that the Multimedia tools used on UI for Autistic children should be as simple as possible because it will seem confusing to the children with ASD (Grynszpan, Martin, and Nadel 2008).

Due to the different needs and different personal preferences in children with ASD, one of the best and successful elements to be considered while designing interventions for them, is personalization (Benton et al. 2011). The benefits and importance of the personalization are also confirmed by (Stern and Shalev 2013).

For designing the UI, recommendations in guideline have been followed, which was set forth by the W3C (World Wide Web Consortium). (Pavlov 2014)

Following that guideline, these are the recommendation for designing an appropriate UI for Autistic individuals: (Pavlov 2014)

2.6.3.2 Interaction

For having a better interaction between the CBI and the user, the following list of required items and the items which are to be avoided is recommended:

Required:

- Design as simple as possible. Few components should be on the screen.
- The buttons on the UI should be large and clear.
- Short instructions (Tooltips) should be given in each step

To be avoided:

- Cluttered and crowded interface.
- Multi-colored icons.
- Buttons with Icon only. Except for the most popular buttons (like Back, Exit, etc.).

2.6.3.3 Presentations

To have a good presentation of the document to the users, the below list of required and non-required items is recommended:

Required:

- A proper contrast should be used between the background and the font.
- Soft and mild colors should be used.

• Textboxes should be separated from the rest of the elements on the UI.

• Words should be presented in a single column.

• Simple graphics should be used on the UI.

• Clear and understandable fonts should be used for the words.

To be avoided:

• Use of bright colors

• Background images for the text.

• Horizontal scrolling on the UI.

2.6.3.4 Navigation and Page Loading

To have useful navigation and fast loading of the pages, the below list of required and non-required items is recommended:

Required:

• The navigation should be clear and simple.

• Mouse or keyboard should support navigation.

• Buttons should be used.

• Loading of pages should be fast.

To be avoided:

• Use of complex menus and functions.

2.6.3.5 Personalization

Finally, to personalize the document presented to each of the users, the following items should be available to be changed by the users.

- Font size and font type.
- Loading of animations and visual elements. (Pavlov 2014).

2.6.4 Demonstration

The main purpose of this stage is to demonstrate the usability of the artifact that has been designed and developed in the previous stage (Peffers et al. 2007). In this research, this stage requires some users to use the artifact and ensure about the usability of the prototype before it is used by the real users or participants (in this case, Autistic children). To do this, we installed the developed Desktop application on one of the PCs in Abdullah Bin Omar high school and requested two students to use it. They noticed some runtime errors while using the prototype and reported it to the authors which were then solved and rebuilt.

The prototype was developed using VB.Net programming language on Microsoft visual studio 2017 environment.

2.6.5 Evaluation

This stage represents the evaluation of the prototype to evaluate the effectiveness of the prototype for the purpose it was developed (Peffers et al. 2007). As long as the prototype in our study is a model which includes speech technology, animations, and game together, for evaluating the prototype, we used a combination of methods and techniques proposed in (Salim et al. 2016), (Bossler and Massaro 2003), and (Comer, Geissler, and Education 1998).

We performed an experimental evaluation of the prototype with the real users of the prototype to ensure the effectiveness of the developed prototype. We installed our prototype to the computers at Hazrat Abdullah Bin Omar high school and let the students use the prototype. We needed to compare our proposed model with an existing speech-based sight word reading intervention for autistic children. Thus, we chose the Computer-Based Sight-Word Reading Intervention (CBSWRI), which is proposed and developed by Jared S. Yaw et al. and is explained in (Yaw et al. 2011).

CBSWRI is a computer-based intervention which is used to teach sight word reading to a 6th-grade autistic student. This program has used Microsoft PowerPoint for word presentation, and some voice recordings were used as a Text-To-Speech for reading the word to the participant (Yaw et al. 2011).

We developed a program with the concept of CBSWRI using Microsoft Windows Text to Speech system and installed it to the computers in Pushta secondary school. The control group of our study was using this program for learning sight word reading during the prototype experiment sessions.

The evaluation part in this step answers the 6th question, which was the last in our Research Questions.

2.6.6 Communication

This is the final stage of this methodology, which represents the findings to the community (Peffers et al. 2007). At the end of this study, the findings of our research and the result of the prototype evaluation will be represented in the form of a dissertation.

CHAPTER 3: PROPOSED MODEL

This chapter introduces the proposed model in this study and describes the design of the proposed model. The components used in the 2 phases of the model have also been discussed at the end of this chapter.

As discussed previously in the review of the literature, CBIs have been used to address different difficulties in children with Autism Spectrum Disorder and most of them have been effective enough for the purposes they have been developed for. Therefore, the proposed model in our research is also a CBI to address reading deficits of the autistic children. For learning purposes, autistic children mostly luck motivation, satisfaction, and attention, and that results in learning disabilities among this population. The main focus of this CBI is to address Motivation, attention, and satisfaction deficits of autistic children, and that will help them to learn English reading. In addition to this, TTS (Text-To-Speech) and ASR (Automatic Speech Recognition) have been used in our proposed model, and that will help this population to improve their interaction with the CBI.

3.1 Design of the proposed Model

As long as this model will deal with autistic children and they are not comfortable with complex menus, functions and a large number of buttons in one page (Asenova 2016; Chen and Waller 2012; Khowaja and Salim 2014; Pavlov 2014; Welch et al. 2010), we decided to develop our model consisting of 2 phases. This helps us to avoid the complexity of the learning intervention and having a simple and understandable user interface for this population. Figure 7 shows the major components of the proposed model.

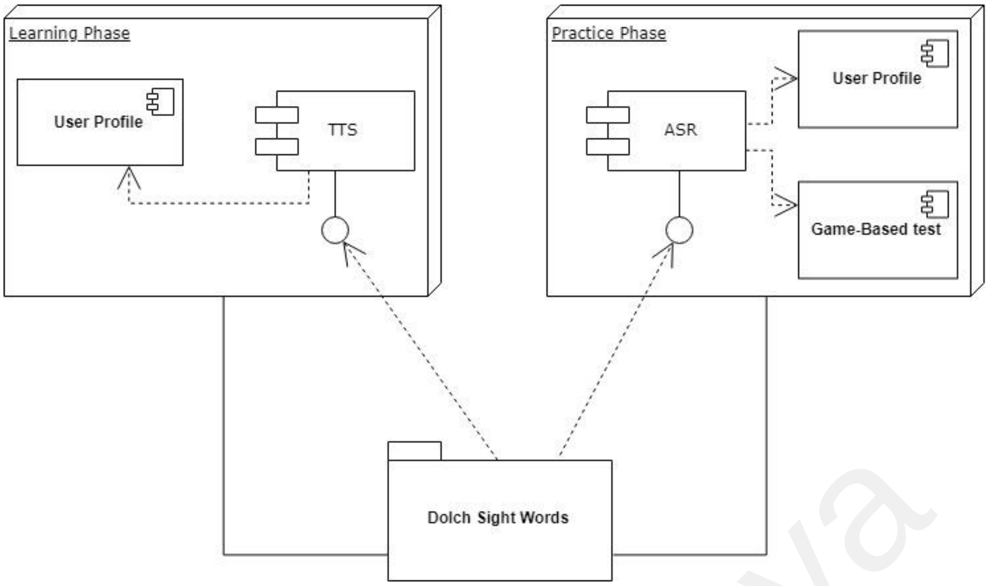

Figure 7: Design components of the proposed model

3.1.1 Design of the learning phase (1st phase)

The first phase in our proposed model will be the learning phase in which the users learn reading the words. In this phase, the users will see one word on the page and they hear the word's pronunciation by the TTS used in the model. There will be a repeat button on this page, which can be used by the users if they wish to hear the word's pronunciation again. The components in this phase have been designed and used in such a way that they can address the main reading difficulties of the autistic children. The detailed information about the components can be found under the "components" title.

3.1.1.1 Components of the learning phase (1st phase)

- Images and Animations

According to Grandin (Grandin 2006; Mayes and Calhoun 2007), to address the attention deficits of autistic children, the use of Multimedia components has been identified as an effective tool by different studies. Therefore, we have used some of the Multimedia components in our model, such as images and animations to gain their attention.

- Dolch 100 sight words

The second element that has been used in this phase of our model is the Dolch 100 sight words. These are the most repeated daily words, and it motivates the autistic children to learn how to read them (Torgesen et al. 1988).

- Progress Bar

The third element in this phase is the progress bar, which shows the learning progress of autistic children. This element helps them know how many words they have learned so far and satisfies them with their progress. One the best ways to satisfy the CBI users while using it for learning purposes is to keep them aware of their current progress (D. J. Brown et al. 1996; Khowaja and Salim 2014).

- Repeat Button

There is a repeat button in the learning phase, which lets the users listen to the word as many times as they want. Pressing this button will let the TTS read the word again and again so that it helps the user in memorizing the word's pronunciation. In short, this button has been used in this phase to address the Memory (Memorization) deficits of the autistic children.

- (Start Animation) Button

There are some cartoon animations in this phase to entertain the autistic children while learning the words but displaying those animations are optional for every single user. As long as autistic children's behaviors are different with the animations in the CBI (K. Higgins and Boone 1996; Zheng et al. 2016), this button is placed in this phase so that they can choose either to have animations in their page or not.

- Next (→) and Previous (←) Buttons

There are two buttons (Arrow-Shaped) in this phase, which are used to switch the existing word to the next word or a previous word. As long as there are 100 sight words used in this phase, the words will be represented to the user one by one and each word is pronounced by the TTS once. If the user could learn reading the word in once, they can go to the next word by pressing Next Button (→ Shape), and if they could not learn the word in once, they can press the repeat button to listen to the word again.

- TTS (Text-To-Speech) technology

To help the users learn how to read a word correctly, the word must be pronounced to them first. For this purpose, the best way is using a TTS (Text-To-Speech) technology in the learning intervention (Engwall, Lopes, and Leite 2017; Y. Huang and Liao 2015; Parr 2013; Zinovjeva 2005). Therefore, we used Microsoft's TTS technology in the learning phase of the proposed model's prototype. This TTS is provided by Microsoft Corporation which exists in Microsoft Windows and is used for .Net applications.

We used The TTS in Microsoft Windows 10 for our developed prototype, which is for English (United States) and have got two voices. The first voice is David's voice, which is a male voice, and the second voice is Zira's voice, which is a female voice (Microsoft Corporation, 2016). The participants can change the gender and reading speed of the TTS reader in the developed prototype. Figure 8 shows the codes for using TTS in our prototype.

As seen in figure 8, TTS is used in the Learning phase of the prototype and it uses Microsoft Windows system's built-in speech synthesis. The variable "synth" was declared as the Speech synthesizer, and it has some features that are possible to be changed. The "synth.Rate" refers to the reading speed of the synthesizer and the users can set it up with their own preferences, and so is the Volume. A combo-box for changing the gender of the reader is used so that the users can change the gender of the reader. "RepresentedWord" is a textbox used in the prototype's learning phase and it takes words from the Dolch 100 Sight words list one by one.

This component addresses the interaction and pronunciation deficits of the autistic children and keeps them interactive with the CBI.

```
imports System.Speech.Synthesis
Public Class LearningPhase
  Private Sub ReadButton_Click(sender As System.Object, e As System.EventArgs) Handles ReadButton_Click
    Dim synth As New SpeechSynthesizer
    synth.Rate = SpeedTrackBar.Value
    synth.Volume = VolumeTrackBar.Value
    If ReaderComboBox.Text = "David" Then
      synth.SelectVoiceByHints(VoiceGender.Male)
    end If
    If ReaderComboBox.Text = "Zira" Then
      synth.SelectVoiceByHints(VoiceGender.Male)
    end If
    synth.Speak(RepresentedWord.Text)
  end Sub
end Class
```

Figure 8: Codes for setting up the TTS

3.1.2 Design of the practice phase (2nd phase)

The second phase in this model is the practice phase in which the users can practice what they have learned earlier in the learning phase. This phase has been designed as a game to encourage autistic children in using it. In this phase, the users will see a word in the top of the page from the list of words that they have already learned in the learning phase. There will be a button at the bottom of the page named (Start). By pressing that button, the word will start moving from the top of the page going to the bottom of the page within 12 seconds. The user needs to read the word aloud so that the ASR can hear the user and can recognize their accuracy in the reading of the word. If the user could pronounce the word accurately, they will get one score in the scores section and the word will be changed to the next word in the list. In case of wrong pronunciation, the user will get negative feedback, and they need to repeat the word before completing 12 seconds. If the user skipped a word, the word would be stored in the user-related record so that it will be presented to them the next time they use the CBI. The components used in this phase are described under components title below.

3.1.2.1 Components of the Practice phase (2nd phase)

- Images and Animations

Same like the learning phase, the visuals have been used in this phase to address the attention deficits of the autistic children. This phase is a game-based phase and the words are moving from the top of the page to the bottom of the page one by one.

- ASR (Automatic Speech Recognition)

To evaluate the reading accuracy and the pronunciation of the users, ASR (Automatic Speech Recognition) has been used in this stage. It helps the autistic children in recognizing their voice and providing them with feedback about their pronunciation. ASR is the most effective way of assessment of the autistic children in reading performances (Balogh et al. 2007; Bejar 2010). ASR also helps autistic children in interaction with the CBI and motivating them in reading the words.

In our proposed model, we have used Microsoft's ASR (Automatic Speech Recognition). Microsoft provides this speech system for .Net applications (Xiong et al.

2018). This system exists in Microsoft Windows and we have used the Continuous Speech recognition, which is Microsoft Windows 10's built-in speech recognition system.

Microsoft Windows 10 is equipped with Windows Speech Recognition version 8.0, which includes Recognition facilities for English, Chinese, Japanese, German, Spanish, and French languages (Microsoft Corporation, 2017).

To use Microsoft's built-in Speech Recognition to a .Net application, we need to import the system's speech libraries to our application development framework. As long as we used VB.Net programming language for developing the prototype, we used some codes which are shown in figure 9 to use Microsoft Windows' built-in Speech Recognition System:

```
using System;
using Microsoft.Speech.Recognition;
using Microsoft.Speech.Synthesis;
using System.Globalization;
namespace ConsoleSpeech
{
  class ConsoleSpeechProgram
  {
    static SpeechSynthesizer ss = new SpeechSynthesizer();
    static SpeechRecognitionEngine sre;
    static bool done = false;
    static bool speechOn = true;
    static void Main(string[] args)
    {
      try
      {
        ss.SetOutputToDefaultAudioDevice();
```

Figure 9: Codes for using speech recognition system in Windows

The above code uses Microsoft's Speech recognition system in Windows, and it creates an environment for synthesizing and recognizing the voice. We defined a Speech synthesizer as (ss) in this case and two boolean variables "done" and "speechOn" to control the recognition process. Whenever a word is displayed to the child, the "speechOn" will be activated and the recognizer starts working and listens to the child.

We connected the speech recognition to the Dolch sight words list and it compares the recognized word with the word given in the words' list.

In the last line of the above code, the "SetOutputToDefaultAudioDevice();" sets the PC's built-in microphone as the default Audio input device and the microphone will be used to hear the voice of the user.

The "speechOn" remains "True" until the word is recognized and it becomes "False" once the word is recognized or if the application is closed. As long as the "speechOn" variable is "True", the system is listening to the user and provides feedback for wrong or correct pronunciations. If a word is correctly pronounced and the system could recognize it, the child will get a score in the practice phase. If the word is pronounced incorrectly, the user has 12 seconds to repeat the word and within 12 seconds if the user couldn't read the word properly, they will lose one of their lives in the practice phase's game. Figure 10 shows the codes for handling the result of the recognition system.

```
static void sre_SpeechRecognized(object sender,
  SpeechRecognizedEventArgs e)
{
  string txt = e.Result.Text;
```

Figure 10: Codes for handling the result of the recognition process

In the above code, we have used a variable "txt" to get the result of the recognition process, which is the recognized speech. We have then compared the text in the "txt" variable to the word which was represented to the user for reading.

- (Start Game) Button

When the user enters the practice page, they will see the very first word of the words-list in the page. They need to press the (Start Game) in order to start practicing the word reading. By pressing this button, the ASR will start working and will listen to the user's voice for recognition. This button is used to help the user start reading a word whenever they are ready for it.

- Score Section

The score section is used in this phase to provide the user with feedback about their pronunciation and motivate the user to read the words. Assessment of reading performance in autistic children is the best way of motivating them in reading and other literacy programs (Choueiri and Zimmerman 2017).

- (Lives) section

As long as this phase is a game-based phase, the (Lives) section has been used in it to encourage the users to read the words accurately. This contains three trials for the user in case of the wrong pronunciation of the words. The user will have three lives when starting this phase, and they will lose one life if they couldn't pronounce the word within 12 seconds. After completing the three lives, the page will be closed and the user needs to open the game again.

- Skip button (→)

This model will deal with autistic children and they might have some pronunciation deficits in the starting. Therefore, this button is used to help the users skip the words which they cannot pronounce them at the moment. The skipped words will be stored in the user record and will be presented to them the next time they log in to the system. This button is used to provide usability of the model to the autistic children.

3.2 User Profile

This proposed model requires a login of the user to get the user profile. This user profile will be used to personalize the system and to present the necessary words to the specific user. Once a user logged in to the system and learned some of the words, the system stores a variable as the progress mark of each user. The next time when the user logs in to the system, the system will recognize the user and will use the progress mark to present the remaining words in the wordlist.

If a user uses this model for the first time, they need to register themselves to the system. Once they are registered to the system, next time they can log in and they will also be recognized by the system and their progress mark will be stored for the next time use. As this system deals with autistic children and they are not comfortable with the crowded tools in a system, the registration has been designed very simple and easy in order to be usable by this population. For registration, the children need to type a username and a password to register themselves as a valid user.

In this model, the words are labeled with a number, which is the index of the array in which the words have been stored. We have used 100 Dolch sight words and this is used in an array of Wordlist [ ]. The wordlist array stores each word with an index, and this index is used to recognize the progress of the user each time they use the system. For example, the word "Farmer" is the 33rd word in the word list, and it is stored with an index of 32 as Wordlist [32]. So, if a child reaches to the word "Farmer" in the learning phase, the index for this word which is 32, is stored as the progress mark for that specific user and next time when the user logs in to the system, the order of the words starts from the word "Farmer". Table 3-1 shows the relation between the user and the variable progress mark.

Table 3-1: User & Progress mark relation example

No	username	password	Progress_mark
1	Anisa	******	[23]
2	Faisal	*****	[35]

Same in the practice phase, if a user practices the words until the word "Farmer", in next time login to the system and opening the practice phase, the game starts from the word after the word "Farmer". Besides, there is another variable in the practice phase, which is the list of the Skipped Words during the practice. If a user could not pronounce a word and the system's ASR could not recognize the word, the system will reduce one mark from the total scores of the user.

In this stage, the user has 10 seconds for each word to pronounce and after 10 seconds, the word will disappear, and the next word will be presented on the screen. So, if a user could not pronounce a word and they want to practice that word at a later time, they can skip the word. In this case, the index for this word will be stored in the list skipped words, and those words will be presented to the user in the next login to the practice phase. Table 3-2 below shows the relation between the user and the progress mark in the practice phase.

Table 3-2: User, progress mark & Skipped words relation in practice phase

No	username	Password	Progress_mark	Skipped_words
1	Sonam	*********	[42]	([12],[23],[27],[33],[39])
2	Bushra	******	[24]	([8],[14],[19])

3.3 100 Dolch sight words

The Dolch word list is a list of frequently used English words compiled by Edward William Dolch, a major proponent of the "whole-word" method of beginning reading instruction. The list was first published in a journal article in 1936 and then published in his book, "Problems in Reading" in 1948. The Dolch 100 sight words list has been used in this model as a database of words. These are the most commonly used nouns and are easy to be read by the children. These words are selected for this model to help autistic children in learning whole-word reading because:

- Children with Autism Spectrum Disorder have difficulties in Phonological Processing (P. Kluth and Chandler-Olcott 2008; Wolk, Edwards, and Brennan 2016).
- Whole-word reading is relative strength in these children (Nation et al. 2006).
- Strengths and visual processing skills have been noted in their ability to process information visually (Allday and Pakurar 2007; Quill 1997).

The Dolch 100 sight words list, which has been used in the current model, is shown in table 3-3.

Table 3-3: List of Dolch 100 sight words

No	Word	No	Word	No	Word	No	Word
1	Apple	26	Dog	51	House	76	Shoe
2	Baby	27	Doll	52	Kitty	77	Sister
3	Back	28	Door	53	Leg	78	Snow
4	Ball	29	Duck	54	Letter	79	Song
5	Bear	30	Egg	55	Man	80	Squirrel
6	Bed	31	Eye	56	Men	81	Stick
7	Bell	32	Farm	57	Milk	82	Street
8	Bird	33	Farmer	58	Money	83	Sun
9	Birthday	34	Father	59	Morning	84	Table
10	Boat	35	Feet	60	Mother	85	Thing
11	Box	36	Fire	61	Name	86	Time
12	Boy	37	Fish	62	Nest	87	Top
13	Bread	38	Floor	63	Night	88	Toy
14	Brother	39	Flower	64	Paper	89	Tree
15	Cake	40	Game	65	Party	90	Watch
16	Car	41	Garden	66	Picture	91	Water
17	Cat	42	Girl	67	Pig	92	Way
18	Chair	43	Good-Bye	68	Rabbit	93	Wind
19	Chicken	44	Grass	69	Rain	94	Window
20	Children	45	Ground	70	Ring	95	Wood
21	Christmas	46	Hand	71	Robin	96	Yellow
22	Coat	47	Head	72	Santa Claus	97	Yes
23	Corn	48	Hill	73	School	98	You
24	Cow	49	Home	74	Seed	99	Your
25	Day	50	Horse	75	Sheep	100	Zoo

CHAPTER 4: MODEL IMPLEMENTATION & DESIGN

This chapter starts with the implementation of the proposed model to design and develop a prototype. In this chapter, the UI design rules and recommendations have been discussed and the screenshots of the developed prototype in this study are also provided.

4.1 Design Implementation

To design a better prototype for autistic children, we needed to consider all the recommendations discussed earlier in chapter 3 and research methodology. As long as the autistic children are not comfortable with lots of tools and buttons in the application, we tried to design the prototype as simple as possible. To avoid confusion in children, we divided the prototype into two separate stages, which are learning stage and practice stage.

To personalize the model for each user and to save the progress record of each user for the next time use of the model, they need to login to the application first. This wants the user to enter a simple username and password for login in order to have a record in the application. Figure 11 below is the first and a login page after starting the application.

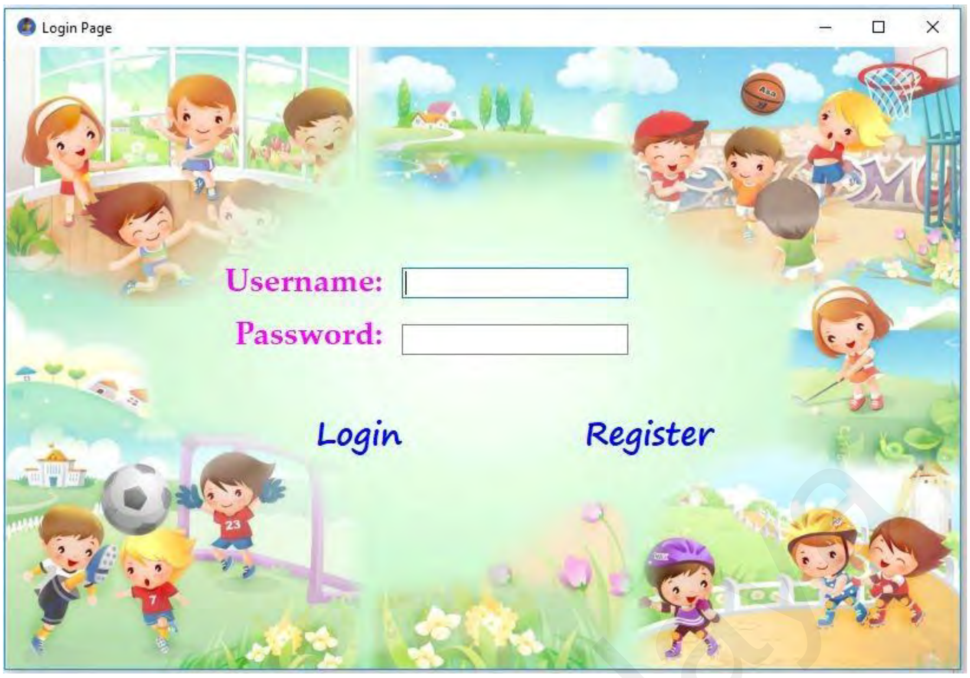

Figure 11: First page of the developed prototype

If the user is already registered with the application, they just need to enter their username and password, and they can log in to the application. In case the user is using the application for the first time, they need to register their username and password first. For this purpose, they need to press the 'Register' button, and they will see the page below:

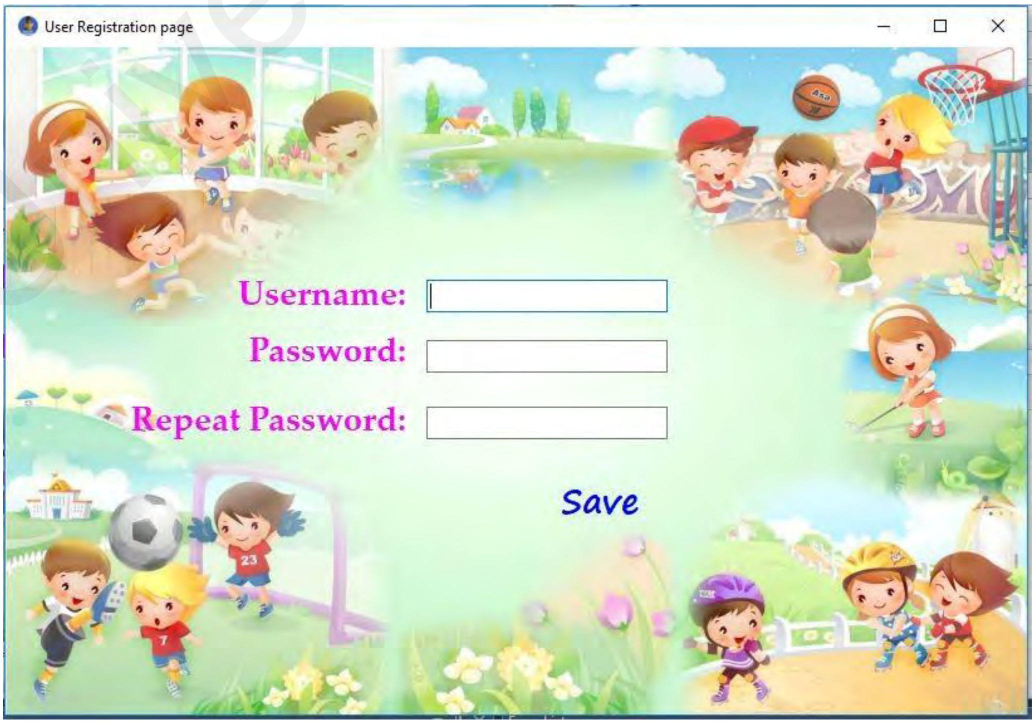

Figure 12: Registration page for first-time users

In the registration page, the user needs to enter a simple username and a password, and then they need to save it. The next time they use the application, they can just simply login to the application with their username and password.

After logging in to the application, the user will see the home page of the application, which is shown in figure 13 below:

Figure 13: Hope page after logging in

After logging in, the user will see and hear a welcome message (Welcome "username"), and they will see two buttons to choose and go to the next page. Each button refers to a stage in the application. We divided the learning process into two stages, the "Learn" stage and the "Practice" stage to avoid complex menus and functions as per Pavlov (Pavlov 2014) UI design guidelines. The first button is the "Learn" button, which opens the learning page of the application, and the second button is the "Practice" button, which opens the Practice page of the application. In the case of pressing the "Learn" button, the user will see the page, which is shown in figure 14 below:

Figure 14: Learning page

In the above page, one word from the list of 100 words is shown to the user in Alphabetic order starting from the word "Apple" and ending with the word "Zoo". For having better usability to the application, the "Back" and "Next" arrows have been used. These buttons are shown in white arrows with green backgrounds and are used to go to the next words or the previous word. In the top right side of the page, a slidebar is used to show the current progress of the user, and it has been used to achieve the satisfaction of the user. At the bottom right side of the application, there is a button "Start Animation". This button has been used to start moving animations and cartoons in the page, and it is button-based because all of the autistic children aren't comfortable with the use of animations in the page, but some of them wish to have these animations when they use applications. Whenever a word is shown to the user, the application will read the word using TTS(Text To Speech), and if the user needs to listen to it more than one time, then they can press the "Repeat" button, and the word will be read to them as per many times they wish to hear. This helps them learn how to read the word correctly.

In the case of pressing the "Practice" button on the home page, the Practice page will be opened to the user, which is shown in figure 15 below:

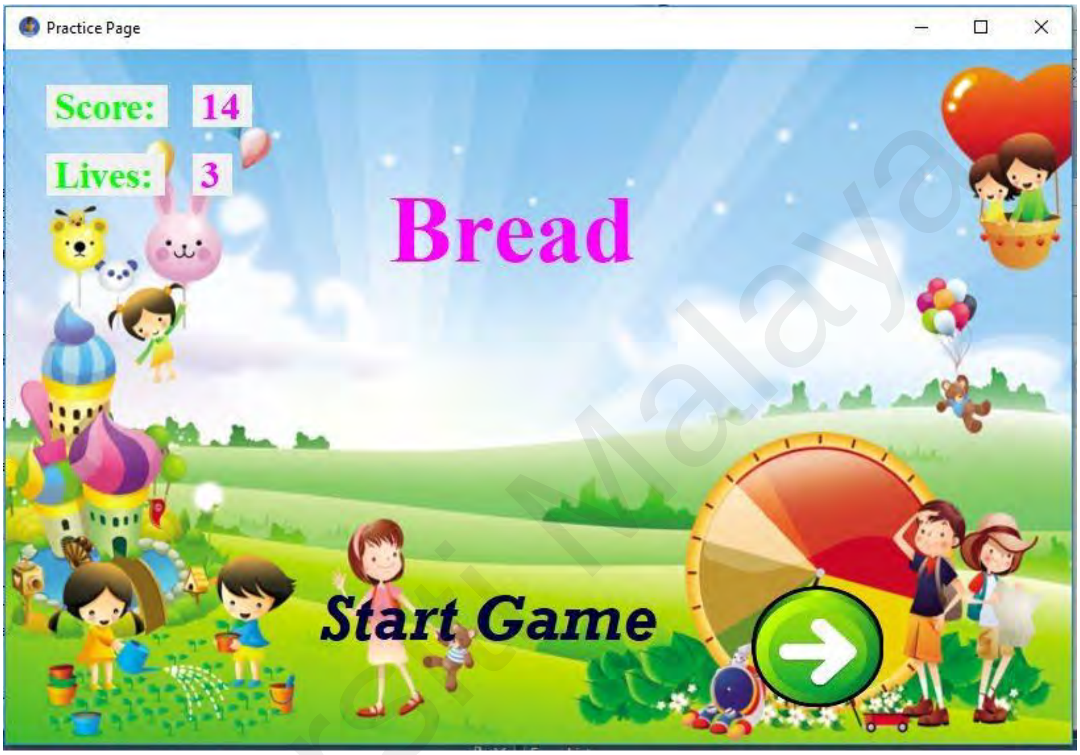

Figure 15: Practice Page

In the practice page, the users can practice the words they have learned earlier on the learning page. The practice phase is designed as a game which will be started by pressing the "Start Game" button down in the middle. When the game starts, a word from the list of words is going down, and the user needs to pronounce it within 12 seconds. If the user could pronounce the word accurately, the existing word will disappear, and the user might get one score in the "Score" section. In case the user could not pronounce the word accurately within the given time (12 Sec), the user will lose one live from the "Live" section in the top left. As long as the users are children and they might have difficulties in pronouncing some of the words, and it is also possible that the ASR (Automatic Speech Recognition) of the system cannot recognize the pronunciation of the child. Therefore, a

“Next” button with white arrow and green background has been used down in the left side of this page, and this helps the user to ignore a word if he/she cannot pronounce it with too many tries. The word which is ignored by the user will be saved in a variable, and next time when the users log into the application, that word will be presented to them to pronounce it.

CHAPTER 5: EVALUATION

5.1 Participants

In this research, we have chosen 26 autistic students from a group of 60 autistic students in 2 schools in Kabul, Afghanistan. The selection criteria for choosing the autistic children were as follows:

1. Autistic students must be between 8 and 14 years old. (16 students who were above 14 years old, were excluded).
2. Autistic students must have deficits in English reading. (12 students were excluded being recognized by the English teachers of the schools).
3. Autistic students must have basic knowledge of using a PC. (6 students were excluded).

From among the selected students, 15 students were students of Hazrat Abdullah Bin Omar high school and the remaining 11 were studying in Pushta secondary school. We considered the first group of students as the experimental group of our research and the second group of students as the control group of our research. Table 5-1 and Table 5-2 show the demographic data of the participants.

5.2 Evaluation Metrics

To evaluate performance and effectiveness of a software system, we used a combination of software quality evaluation methods proposed in (Barkmann, Lincke, and Löwe 2009; Comer, Geissler, and Education 1998; Jeanrenaud and Romanazzi 1994). In this method, we let the users use the system for some time, and we evaluated the performance of the users while using the system, comparing who used a different system. At the end of this experience, we compared the result of the group of users who used our proposed model’s prototype and those who used Computer-Based Sight-Word Reading Intervention (CBSWRI).

Table 5-1: Demographic data of the students in Pushta Secondary school

No	Name	F/Name	Age	Class	Gender
1	Aayesha	Rahmat Shah	10	3	Female
2	Beheshtah	Nabiullah	10	3	Female
3	Khorshid	Noor Aagha	10	2	Female
4	Aarastah	Masihullah	9	2	Female
5	Saarah	Abdul Wahed	9	2	Female
6	Khadijah	Ali Ahmad	8	2	Female
7	M. Esmail	Rabiullah	10	3	Male
8	Abdul Rahman	Abdul Jamil	9	3	Male
9	Abdullah	Rohullah	9	2	Male
10	Edris Ahmad	Azimullah	8	2	Male
11	Abdul Qayoom	Ghulam Eshan	8	2	Male

Table 5-2: Demographic data of the students in Hazrat Abdullah Bin Omar

No	Name	F/Name	Age	Class	Gender
1	Saaberah	Abdul Rahman	9	3	Female
2	Marwah	Sayed Sadeq	9	2	Female
3	Bushra	Ahmad Shah	8	2	Female
4	Abbas	Abdul Wudood	10	3	Male
5	Ansarullah	Abdul Hashem	10	3	Male
6	M. Subhan	Amir Muhammad	9	3	Male
7	Suhail	M. Azam	9	3	Male
8	M. Ayaz	Khan Muhammad	9	2	Male
9	Muhammad	Mehdi	9	2	Male
10	M. Mansoor	Muhammad Gul	8	2	Male
11	Noor Ahmad	Wali Muhammad	8	2	Male
12	M. Mujtaba	Ata Muhammad	8	2	Male
13	M. Issa	Rohullah	8	2	Male
14	Abdul Musawer	Habib Rahman	8	2	Male
15	Mustafa	Raz Muhammad	8	2	Male

For the evaluation purpose, we selected 15 of the autistic students as the experimental group and let them use the developed prototype of the proposed model of this study while 11 other students were considered as the control group. The control group in this study were students of Pushta Secondary school and they used Computer-Based Sight-Word Reading Intervention (CBSWRI) for learning sight words.

Studies show that the best way of testing speech-based computer interventions is the Word Error Rate (WER) (Këpuska 2017; Xiong et al. 2018; Xuedong Huang et al. 2002). Therefore, we chose WER as the evaluation metrics for this study. We conducted a post-test of Sight word reading and tested the reading accuracy rate among the students of both groups. Each student was given a bunch of 20 Sight words in a time limit of 10 minutes. If the student could read a word accurately within 30 seconds, they were given one mark for a correct word, otherwise, 0 marks for reading incorrectly.

By modifying the codes of ASR in the practice page of the prototype, we could come up with a speech-based test environment. This page was the same as the practice page of the prototype with some differences. In this page, there were 20 sight words which were chosen for the post-test, and the users had 10 minutes in total to read the words accurately. For every word, the user got 30 seconds to read it, and after 30 seconds, the word was disappeared, and a new word was on the screen. We modified the code so that the speech recognizer listens to the user for 30 seconds and if the user could read the word correctly within 30 seconds, they were given one mark, and if not, they were given 0, and the next word in the list was shown to them on the screen.

At the end of this experiment, we compared the results of post-test for both groups to see if the proposed model helped the students better than the existing system.

5.3 Procedure

We followed the evaluation methods proposed by other researchers and we performed it in 4 stages, which are: Introduction to the program and evaluation process, English pre-test, prototype usage, and English post-test.

5.3.1 Introduction to the program and evaluation process

In this stage, we conducted two seminars of 2 hours each for the selected students in this study to make them familiar with the evaluation procedures and the experiment details. This helped us ignore each time description of everything for every single person involved in the evaluation procedure. The first seminar was conducted in Hazrate Abdullah bin Omar high school for the experimental group, and the second seminar was conducted in Pushta Secondary school for the control group in this study. In these seminars, the participants learned how this experiment works and how to use the computer-based interventions involved in this experiment.

5.3.2 English pre-test

To have a comparative result of the students before and after using the prototype, we conducted a pre-test of English words for the selected students. The pre-test was a paper-based test and was conducted by the English teachers of both schools.

In this test, a group of 20 easy 1st grade words (Dolch 1st grade words) was selected to test the word reading accuracy of the students. Each word worth one mark if it is read accurately, and the total mark for this test was 20 marks. Table 5-3 shows the pre-test result of the students. These marks are given upon the word reading accuracy of the students by their English teachers.

Table 5-3: Marks for the English pre-test

No	Name	Score	No	Name	Score
1	Aayesha	4	14	Bushra	4
2	Beheshtah	7	15	Abbas	6
3	Khorshid	5	16	Ansarullah	6
4	Aarastah	8	17	M. Subhan	5
5	Saarah	6	18	Suhail	4
6	Khadijah	5	19	M. Ayaz	5
7	M. Esmail	6	20	Muhammad	6
8	Abdul Rahman	4	21	M. Mansoor	4
9	Abdullah	6	22	Noor Ahmad	5
10	Edris Ahmad	4	23	M. Mujtaba	7
11	Abdul Qayoom	5	24	M. Issa	6
12	Saaberah	7	25	Abdul Musawer	5
13	Marwah	5	26	Mustafa	6

5.3.3 Prototype usage (Experiment)

This is the main stage for evaluation. To evaluate the prototype, we installed the developed prototype into 15 PCs in Hazrat Abdullah Bin Omar high school. This stage was a 2-week long stage which consists of 10 sessions. Each session was for 40 minutes and five sessions per week (the schedule for the English language is five sessions per week in those schools).

The PCs were placed in 2 large computer laboratories at the Abdullah bin Omar high school, and 7 & 8 students were sitting in each class at the same time to avoid noise and disturbance while using the prototype.

The 15 selected students of Hazrate Abdullah bin Omar high school were the experimental group of this study, and the remaining 11 students of Pushta secondary school were the control group for this experiment.

At the same time, We installed the CBSWRI-based application into 11 PCs in Pushta secondary school for the control group, and they were using this application for learning sight word reading.

The proposed model's prototype was being used by the 15 students, and the remaining 11 were using Computer-Based Sight-Word Reading Intervention (CBSWRI) at Pushta secondary school.

5.3.4 English post-test

At the end of the ten sessions, we conducted a post-test of the whole group of 26 students, and the result for the post-test is described in table 5-4 below. In post-test also like the pre-test, a total of 20 words were chosen for the students and students needed to read them accurately. These 20 words were selected from among the 100 Dolch sight words which were already taught to both the groups during the previous stage.

Table 5-4: Marks for the English Post-test

No	Name	Score	No	Name	Score
1	Aayesha	8	14	Bushra	15
2	Beheshtah	12	15	Abbas	16
3	Khorshid	10	16	Ansarullah	17
4	Aarastah	11	17	M. Subhan	18
5	Saarah	9	18	Suhail	13
6	Khadijah	11	19	M. Ayaz	12
7	M. Esmail	9	20	Muhammad	11
8	Abdul Rahman	8	21	M. Mansoor	18
9	Abdullah	9	22	Noor Ahmad	16
10	Edris Ahmad	11	23	M. Mujtaba	15
11	Abdul Qayoom	10	24	M. Issa	14
12	Saaberah	15	25	Abdul Musawer	17
13	Marwah	14	26	Mustafa	15

5.4 Tools

The tools used in this stage for evaluation purpose are as follows:

1. A group of 20 easy words (1st grade Dolch sight words) for the pre-test. Table 5-5 shows the 20 easy words for the pre-test.

Table 5-5: 20 Easy words for the English pre-test

No	Word	No	Word
1	As	11	give
2	Any	12	how
3	Ask	13	Old
4	By	14	Put
5	Fly	15	Stop
6	From	16	Take
7	Has	17	Thank
8	Just	18	Walk
9	Let	19	Were
10	may	20	when

2. A group of 100 Dolch sight words was used in the prototype and CBSWRI-based application for learning and practice parts of the application. Table 5-6 shows the 100 Dolch sight words for the prototype.

3. 15 Desktop PCs (Equipped with a headphone) in Hazrat Abdullah bin Omar high school were used to install the prototype in and 11 PCs in Pushta secondary school to install CBSWRI-based application in.

4. A group of 20 words was selected from the 100 Dolch sight words for the post-test. Table 5-7 shows these 20 words for the post-test.

5. Microsoft Excel was used for drawing the charts and graphs of the collected data. The graphs were used for presenting the results of the pre-test and post-test of the participants to make it easy to understand and analyze for further decision on the effectiveness of the model's prototype.

Table 5-6: Dolch 100 sight words

No	Word	No	Word	No	Word	No	Word
1	Apple	26	Dog	51	House	76	Shoe
2	Baby	27	Doll	52	Kitty	77	Sister
3	Back	28	Door	53	Leg	78	Snow
4	Ball	29	Duck	54	Letter	79	Song
5	Bear	30	Egg	55	Man	80	Squirrel
6	Bed	31	Eye	56	Men	81	Stick
7	Bell	32	Farm	57	Milk	82	Street
8	Bird	33	Farmer	58	Money	83	Sun
9	Birthday	34	Father	59	Morning	84	Table
10	Boat	35	Feet	60	Mother	85	Thing
11	Box	36	Fire	61	Name	86	Time
12	Boy	37	Fish	62	Nest	87	Top
13	Bread	38	Floor	63	Night	88	Toy
14	Brother	39	Flower	64	Paper	89	Tree
15	Cake	40	Game	65	Party	90	Watch
16	Car	41	Garden	66	Picture	91	Water
17	Cat	42	Girl	67	Pig	92	Way
18	Chair	43	Good-Bye	68	Rabbit	93	Wind
19	Chicken	44	Grass	69	Rain	94	Window
20	Children	45	Ground	70	Ring	95	Wood
21	Christmas	46	Hand	71	Robin	96	Yellow
22	Coat	47	Head	72	Santa Claus	97	Yes
23	Corn	48	Hill	73	School	98	You
24	Cow	49	Home	74	Seed	99	Your
25	Day	50	Horse	75	Sheep	100	Zoo

Table 5-7: List of the selected 20 words for the English Post-test

No	Word	No	Word
1	Back	11	Kitty
2	Bell	12	Letter
3	Bread	13	Morning
4	Cake	14	Night
5	Chair	15	Rabbit
6	Christmas	16	Sheep
7	Door	17	Table
8	Farmer	18	Watch
9	Garden	19	Wood
10	Head	20	Yellow

5.5 Results & Discussion

During the Pre-test and post-test, a collection of 40 words were presented to the students of both groups. During the pre-test, the experimental group could read an average of 5.4 words accurately which becomes 27% of the total of 20 words, and the control group could read an average of 5.45 words accurately which is 27.25% of the total of 20 words presented to them. The result of the pre-test shows both groups of students have the almost same level of knowledge in Engish reading. Although the words in the pre-test were so easy, still the participants had difficulties in reading the words correctly.

Similarly, during the post-test, a group of 20 Dolch sight words was chosen, which had been used in the prototype and were also used in the CBSWRI-based application to be presented to the control group.

Among the students in the experimental group, Saaberah could read 15 words out of 20 correctly, Marwah 14 words, Bushra 15 words, Abbas 16 words, Ansarullah 17 words, M. Subhan 18 words, Suhail 13 words, M. Ayaz 12 words, Muhammad 11 words, M.

Mansoor 18 words, Noor Ahmad 16 words, M. Mujtaba 15 words, M. Issa 14 words, Abdul Musawer 17 words, and Mustafa 15 words. In total, the experimental group could recognize 15.06 out of 20 words accurately in average, which becomes 75.3% of the total 20 words.

Among the students in the control group, as an average, the participants could recognize 9.81 words accurately, which becomes 49.05% of the whole 20 words. As a result, the students in the experimental group could recognize an average of 5.25 words more than the control group, which shows a difference of 26.05%. This shows that the experimental group performed better than the control group in reading the words accurately.

The result of the post-test among the students of both groups shows that there was a significant difference (26.05%) between the results of the experimental group and the control group and it shows that the prototype affected the performance of the students in learning English sight word reading. Figure 16 and figure 17 show the graph of the results of the students for the pre-test and post-test of both the groups. The Normal line represents the marks for the control group while the dashed line represents the marks for the experimental group.

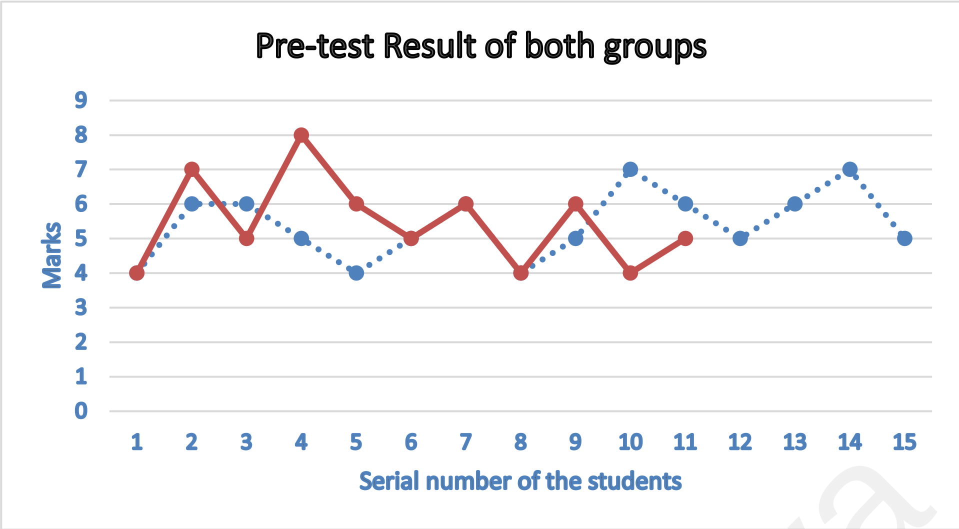

Figure 16: The result for the Pre-test of both the groups

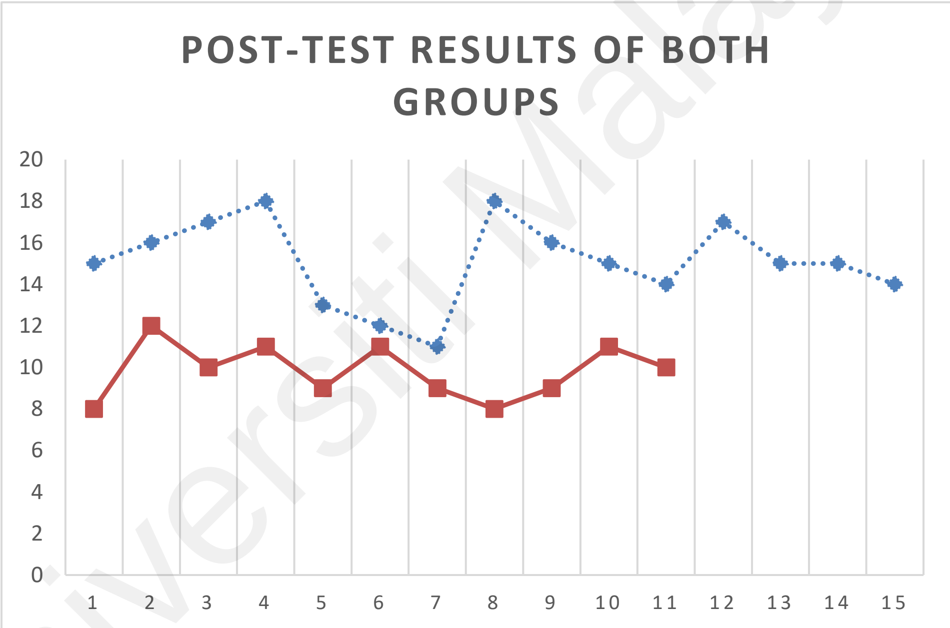

Figure 17: The result for the Post-test of both the groups

In the charts above, the normal line shows the result of the control group, while the dashed line shows the result of the experimental group.

CHAPTER 6: CONCLUSION

This study was conducted to address the English reading difficulties in Autistic children. After developing the speech-based CBI, it was presented to 15 autistic students to use it as an intervention to learn English reading. The students learned to use the program, and they showed an interest in using it. We evaluated the English reading skills of these 15 children who used this prototype with a contrast group of 11 students who used CBSWRI-based program, and the result shows a significant improvement in English reading skills of autistic children who used the proposed model's prototype of this study. We conducted a pre-test and a post-test among the participants in both groups. During the pre-test, before using the prototype, both groups performed almost the same; the experimental group could read an average of 5.4 out of 20 words, and the control group could read an average of 5.45 out of 20 words accurately but during the post-test, the experimental group could read an average of 15.06 out of 20 words while the control group could read an average of 9.81 out of 20 words which shows a difference of 26.05%. The result shows that the speech-based CBI was more effective to address the reading deficits of the children compared to the CBSWRI, which is not a speech-based CBI. The findings also suggest that the components used in the CBI, well addressed the deficits they were used for, and the students' feedback about those components was positive and satisfying. Both speech systems (ASR and TTS) were very useful and effective in attracting the users' attention and helping them in learning better. The speech systems also helped the students to pronounce better and learn how to read correctly. In the end, the use of speech-based CBI is considered as an appropriate tool to teach reading comprehension and sentence combination to this population.

REFERENCES

Abidoğlu, Ülkü, Oya Ertuğruloğlu, and Niyal Büyükeğilmez. 2017. "Importance of Computer-Aided Education for Children with Autism Spectrum Disorder (ASD)." *Eurasia Journal of Mathematics, Science and Technology Education* 13(8): 4957–64. http://www.journalssystem.com/ejmste/Importance-of-Computer-Aided-Education-for-Children-with-Autism-Spectrum-Disorder,76267,0,2.html.

Aljameel, Sumayh S., James D. O'Shea, Keeley A. Crockett, and Annabel Latham. 2018. "A Review of Current Technology-Based Intervention for School Aged Childen with Autism Spectrum Disorder." *Proceedings of SAI Intelligent Systems Conference*: 869–79.

Allday, R. A., and K. Pakurar. 2007. "Effects of Teacher Greetings on Student On-Task Behavior." *Journal of Applied Behavior Analysis* 40(2)(4th Ed.): 317–20.

American Psychiatric Association. 2000. 3 *Diagnostic and Statistical Manual of Mental Disorders 4*. http://www.apa.org.

Anderson-Inman, Lynne, and Mark A. Horney. 2007. "Supported EText: Assistive Technology through Text Transformations." *Reading Research Quarterly* 42(1): 153–60. http://doi.wiley.com/10.1598/RRQ.42.1.8.

Anderson, Richard C. et al. 1988. "Becoming a Nation of Readers: The Report of the Commission on Reading." *Education and Treatment of Children* 11. http://www.jstor.org/stable/42899086.

Anwar, Anika et al. 2011. "A Computer Game Based Approach for Increasing Fluency in the Speech of the Autistic Children." *Proceedings of the 2011 11th IEEE International Conference on Advanced Learning Technologies, ICALT 2011* (Cdc):

17–18. http://www.scopus.com/inward/record.url?eid=2-s2.0-80052756511&partnerID=tZOtx3y1.

Aresti-Bartolome, Nuria, and Begonya Garcia-Zapirain. 2014. "Technologies as Support Tools for Persons with Autistic Spectrum Disorder: A Systematic Review." *International Journal of Environmental Research and Public Health* 11(8): 7767–7802.

Asenova, Ivanka V. 2016. "Lateral Preferences in Autistic Children with Severe Language Impairment." *Procedia - Social and Behavioral Sciences* 217: 84–91.

Autism Spectrum Australia. 2018. *What Are Autism Spectrum Disorders?* https://www.autismspectrum.org.au/sites/default/files/Kevin/What is ASD Fact Sheet.pdf.

Bahl, L R, P F Brown, P V de Souza, and R L Mercer. 1986. "Maximum Mutual Information Estimation of {HMM} Parameters for Speech Recognition." *Proc. IEEE Intl. Conf. on Acoustic, Speech and Signal Processing*: 49–52. https://doi.org/10.1109/ICASSP.1990.115863.

Baio, J. 2014. "Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years." *Morbidity and Mortality Weekly Report* (May): 1–14. http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6302a1.htm?s_cid=ss6302a1_w.

Balogh, J, J Bernstein, J Cheng, and B Townshend. 2007. "Automatic Evaluation of Reading Accuracy: Assessing Machine Scores." *Proceedings of {SLaTE} {ITWR} Workshop* (of 8): 112–15.

Banire, Bilikis, Nazean Jomhari, and Rodina Ahmad. 2015. "Visual Hybrid Development Learning System (VHDLS) Framework for Children with Autism." *Journal of*

Autism and Developmental Disorders 45(10): 3069–84.

Banire, Bilikis, Dena Al Thani, Marwa Qaraqe, and Bilal Mansoor. 2017. "A Systematic Review: Attention Assessment of Virtual Reality Based Intervention for Learning in Children with Autism Spectrum Disorder." *2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)* (November): 97–103. http://ieeexplore.ieee.org/document/8284387/.

Barkmann, Henrike, Rüdiger Lincke, and Welf Löwe. 2009. "Quantitative Evaluation of Software Quality Metrics in Open-Source Projects." *Proceedings - International Conference on Advanced Information Networking and Applications, AINA*: 1067–72.

Bejar, Isaac I. 2010. "Can Speech Technology Improve Assessment and Learning ? New Capabilities May Facilitate Assessment Innovations." (15): 1–8.

Benton, Laura et al. 2011. "IDEAS: An Interface Design Experience for the Autistic Spectrum." *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems*: 1759–64.

Bernard-opitz, Vera, N Sriram, and Sharul Nakhoda-sapuan. 2001. "Problem-Solving_Bernard-Opitz-et-Al_2001." 31(4).

Bölte, Sven, Ofer Golan, Matthew S. Goodwin, and Lonnie Zwaigenbaum. 2010. "What Can Innovative Technologies Do for Autism Spectrum Disorders?" *Autism* 14(3): 155–59. http://journals.sagepub.com/doi/10.1177/1362361310365028.

Bossler, a, and D W Massaro. 2003. "Development and Evaluation of a Computer-Animated Tutor for Vocabulary Learning for Children with Autism." *J Autism Dev Disord* 33(6): 653–72.

Boucenna, Sofiane et al. 2014. “Interactive Technologies for Autistic Children: A Review.” *Cognitive Computation* 6(4): 722–40.

Bouck, Emily C., Nancy K Meyer, and Gauri S. Joshi. 2013. “Accessing Algebra via MathSpeak™: Understanding the Potential and Pitfalls for Students with Visual Impairments.” *Journal of Special Education Technology* 28(1): 49–63.

Bouck, Emily C, Sara Flanagan, and Gauri S Joshi. 2011. “Speaking Math – A Voice Input, Speech Output Calculator for Students with Visual Impairments.” *Journal of Special Education Technology* 26(4): 1–14.

Brown, David J et al. 1996. “For the Production of Virtual Learning Environments for Use By.” *Gesture*: 401–15.

Brown, Heather, Janis Oram-Cardy, and Andrew Johnson. 2013. 43 Journal of Autism & Developmental Disorders *A Meta-Analysis of the Reading Comprehension Skills of Individuals on the Autism Spectrum*. http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=86169829&site=ehost-live%5Cnhttp://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=86169829&S=R&D=ehh&EbscoContent=dGJyMNXb4kSepq84zdnyOLCmr0yep7NSs664SrOWxWXS&ContentCustomer=dGJyMPGorkywqLd.

Buescher, Ariane V.S., Zuleyha Cidav, Martin Knapp, and David S. Mandell. 2014. “Costs of Autism Spectrum Disorders in the United Kingdom and the United States.” *JAMA Pediatrics* 168(8): 721–28.

Cassidy, S. A. et al. 2016. “Expressive Visual Text-to-Speech as an Assistive Technology for Individuals with Autism Spectrum Conditions.” *Computer Vision and Image*

Understanding 148: 193–200.

Chen, H Pain Á A Alcorn Á J, and R Menzies Á A Waller. 2012. “Developing Technology for Autism : An Interdisciplinary Approach.” *Pers Ubiquit Comput (2012)* 16: 117–27.

Chou, Chien Hsing, Yung Long Chu, and Hui Ju Chen. 2017. “A Mandarin Phonetic-Symbol Communication Aid Developed on Tablet Computers for Children with High-Functioning Autism.” *Journal of Applied Science and Engineering* 20(2): 251–58.

Choueiri, Roula N., and Andrew W. Zimmerman. 2017. “New Assessments and Treatments in ASD.” *Current Treatment Options in Neurology* 19(2).

CogSci MQ, and Jon Brock. 2018. “What Is Autism?” *American Autism Society*: 1–2. http://www.autism-society.org/what-is/.

Coleman, Mari Beth et al. 2015. “Teaching Sight Words to Elementary Students with Intellectual Disability and Autism: A Comparison of Teacher-Directed versus Computer-Assisted Simultaneous Prompting.” *Intellectual and Developmental Disabilities* 53(3): 196–210.

Comer, F G, Colin Geissler, and Society for Information Technology and Teacher Education. 1998. “ A Methodology for Software Evaluation.” *SITE 98 Conference - Society for Information Technology and Teacher Education* (5). http://rkenner.concordia.ca/Teslpapers/Methodwebpage/tableofcontents.html.

Cronin, Kathleen A. 2014. “The Relationship Among Oral Language, Decoding Skills, and Reading Comprehension in Children with Autism.” *Exceptionality* 22(3): 141–57.

Cunningham, James W. 2001. "The National Reading Panel Report." *Reading Research Quarterly* 36(3): 326–35. http://search.proquest.com/docview/212131911?accountid=14741%5Cnhttp://dos-sfx.hosted.exlibrisgroup.com/dosbunche?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=unknown&sid=ProQ:ProQ%3Apqrl&atitle=The+National+Reading+Panel+Report&titl.

Deng, Li et al. 2013. "Recent Advances in Deep Learning for Speech Research at Microsoft." *ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing - Proceedings*: 8604–8.

Department of Health (UK). 2009. "Basic Guidelines for People Who Commission Easy Read Information." (Office of the National Director of Learning Disabilities). http://www.easy-read-online.co.uk/media/10612/comm basic guidelines for people who commission easy read info.pdf.

Dunlap, Glen, and Jonathan Worcester. 2001. "ABA and Academic Instruction." *Focus on Autism and Other Developmental Disabilities* 16(2): 129–36.

Ehsani, Farzad, and Eva Knodt. 1998. "Speech Technology in Computer-Aided Language Learning: Stengths and Limitations of a New CALL Paradigm." *Language Learning & Techonology* 2(1): 54–72.

Engwall, Olov, Jose Lopes, and Iolanda Leite. 2017. *Speech and Language Technology in Education*. KTH Royal Institute of Technology, SE-100 44 stockholn, Sweden. https://github.com/giampierosalvi/LaTeXProceedings.

Fletcher-Watson, Sue. 2014. "A Targeted Review of Computer-Assisted Learning for People with Autism Spectrum Disorder: Towards a Consistent Methodology."

Review Journal of Autism and Developmental Disorders 1(2): 87–100.

Fombonne, Eric. 2005. "The Changing Epidemiology of Autism. [References]." *Journal of Applied Research in Intellectual Disabilities* 18(4): 281–94. http://onlinelibrary.wiley.com/doi/10.1111/j.1468-3148.2005.00266.x/full.

Freyhoff, Geert et al. 1998. "Make It Simple." (June). http://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1271&context=gladnetcollect.

Garrett, Jennifer Tumlin et al. 2011. "Using Speech Recognition Software to Increase Writing Fluency for Individuals with Physical Disabilities." *Journal of Special Education Technology* 26(1): 25–41.

Goldson, Edward. 2001. "Educating Children with Autism." *Journal of Developmental & Behavioral Pediatrics* 25(6): 435.

Grandin, Temple. 2006. "Thinking in Pictures: And Other Reports from My Life with Autism." *Vintage*.

Grigorenko, Elena L., Ami Klin, and Fred Volkmar. 2003. "Annotation: Hyperlexia: Disability or Superability?" *Journal of Child Psychology and Psychiatry and Allied Disciplines* 44(8): 1079–91.

Grynszpan, Ouriel, Jean Claude Martin, and Jacqueline Nadel. 2008. "Multimedia Interfaces for Users with High Functioning Autism: An Empirical Investigation." *International Journal of Human Computer Studies* 66(8): 628–39.

Harrington, John W, and Korrie Allen. 2014. "The Clinician ' s Guide to Autism." *Pediatrics in review / American Academy of Pediatrics* 35(2): 62–78.

Hauskrecht, Milos. 2014. "Designing a Learning System." (July): 1–3. http://www.cs.pitt.edu/~milos/courses/cs2750/.

Higgins, Eleanor L., and Marshall H. Raskind. 2004. "Speech Recognition-Based and Automaticity Programs to Help Students with Severe Reading and Spelling Problems." *Annals of Dyslexia* 54(2): 365–88. http://link.springer.com/10.1007/s11881-004-0017-9.

Higgins, K., and R. Boone. 1996. "Creating Individualized Computer-Assisted Instruction for Students with Autism Using Multimedia Authoring Software." *Focus on Autism and Other Developmental Disabilities* 11(2): 69–78.

Hincks, Rebecca. 2005. *Computer Support for Learners of Spoken English*.

Huang, By Xuedong, James Baker, and Raj Reddy. 2014. "A Historical Perspective of Speech Recognition." *Communication of The ACM* 57.

Huang, X. et al. 2001. "MIPAD : A MULTIMODAL INTERACTION PROTOTYPE " • " —." *Speech Technology Group (Microsoft Research)*. http: / /research.microsoft.com/stg.

Huang, Yi-ching, and Lung-chuan Liao. 2015. "A STUDY OF TEXT-TO-SPEECH (TTS) IN CHILDREN ' S ENGLISH LEARNING." *Teaching English with Technolog* 15(1): 14–30.

Iacono, Teresa, Susan Balandin, and Linda Cupples. 2001. "Focus Group Discussions of Literacy Assessment and World Wide Web-Based Reading Intervention." *AAC: Augmentative and Alternative Communication* 17(1): 27–36.

Jeanrenaud, A., and P. Romanazzi. 1994. "Software Product Evaluation Metrics: A

Methodological Approach.” 9.

Kanner, Leo. 1943. “Autistic Disturbances of Affective Contact.” *Nervous Child* 2: 217–50.

Këpuska, Veton. 2017. “Comparing Speech Recognition Systems (Microsoft API, Google API And CMU Sphinx).” *International Journal of Engineering Research and Applications* 07(03): 20–24.

Khowaja, Kamran, and Siti Salwah Salim. 2013. “A Systematic Review of Strategies and Computer-Based Intervention (CBI) for Reading Comprehension of Children with Autism.” *Research in Autism Spectrum Disorders* 7(9): 1111–21. http://dx.doi.org/10.1016/j.rasd.2013.05.009.

———. 2014. “Design Components for Serious Games of Children with Autism Spectrum Disorder (ASD).” (May).

Kittel, Pamela R. 2013. “Predictors of Basic Reading Skills in High-Functioning Children with Autism Spectrum Disorder : The Role of Cognitive Flexibility By.”

Kluth, P., and K. Chandler-Olcott. 2008. *A Land We Can Share (Teaching Literacy to Students with Autism)*. Paul H. Brookes Publishing.

Kluth, Paula, and Julie Darmody. 2003. “Beyond Sight Words: Literacy Opportunities for Students with Autism.” *The Reading Teacher* 56(6): 532–35. http://www.jstor.org/stable/20205240.

Knight, Victoria, Bethany R. McKissick, and Alicia Saunders. 2013. “A Review of Technology-Based Interventions to Teach Academic Skills to Students with Autism Spectrum Disorder.” *Journal of Autism and Developmental Disorders* 43(11): 2628–

48.

Lavie, Nilli. 2010. “Attention, Distraction, and Cognitive Control under Load.” *Current Directions in Psychological Science* 19(3): 143–48.

Lee, Kai Fu, Hsiao Wuen Hon, and Raj Reddy. 1990. “An Overview of the SPHINX Speech Recognition System.” *IEEE Transactions on Acoustics, Speech, and Signal Processing* 38(1): 35–45.

Leong, Che Kan. 1992. “Enhancing Reading Comprehension with Text-to-Speech (DECtalk) Computer System.” *Reading and Writing* 4(2): 205–17.

Limoges, Élyse et al. 2005. “Atypical Sleep Architecture and the Autism Phenotype.” *Brain* 128(5): 1049–61.

Lin, Chu-Sui, Shu-Hui Chang, Wen-Ying Liou, and Yu-Show Tsai. 2013. “The Development of a Multimedia Online Language Assessment Tool for Young Children with Autism.” *Research in Developmental Disabilities* 34(10): 3553–65. http://dx.doi.org/10.1016/j.ridd.2013.06.042%0Ahttp://linkinghub.elsevier.com/retrieve/pii/S0891422213002916%0Ahttp://booksc.org/book/23596371.

Liu, Ying et al. 2007. “Using Visual Speech for Training Chinese Pronunciation: An in-Vivo Experiment.” *SLaTE Workshop on Speech and Language Technology in Education. ISCA Tutorial and Research Workshop. The Summit Inn, Farmington, Pennsylvania USA* (SLaTE): 29–32. http://www.isca-speech.org/archive_open/archive_papers/slate_2007/sle7_029.pdf.

Lyon, G. Reid. 2001. “Measuring Success: Using Assessments and Accountability to Raise Student Achievement. Statement of Dr. G. Reid Lyon, Chief.”

Malaysian Ministry of health. 2014. *Management of Autism Spectrum Disorder in Children and Adolescents*. Kuala Lumpur: Malaysian Health Technology Assessment Section (MaHTAS) Medical Development Division, Ministry of Health Malaysia. http://www.moh.gov.my/penerbitan/CPG2017/CPG_Management_of_Autism.pdf.

Marks, S. U. et al. 2003. “Instructional Management Tips for Teachers of Students with Autism Spectrum Disorder.” *Teaching Exceptional Children* 35(4): 50–54.

Mayes, Susan Dickerson, and Susan L. Calhoun. 2007. “Learning, Attention, Writing, and Processing Speed in Typical Children and Children with ADHD, Autism, Anxiety, Depression, and Oppositional-Defiant Disorder.” *Child Neuropsychology* 13(6): 469–93.

McPartland, J. C., K. Law, and G. Dawson. 2015. “Autism Spectrum Disorder.” *Encyclopedia of Mental Health: Second Edition* 1(4): 124–30.

Miles, Judith H. 2011. “Autism Spectrum Disorders-A Genetics Review.” *Genetics in Medicine* 13(4): 278–94.

Murray, Dinah KC. 2011. 3 *Autism and Information Technology: Therapy with Computers*. Autism and Learning (Classic Edition).

Nally, Amanda, Olive Healy, Jennifer Holloway, and helena Lydon. 2018. “An Analysis of Reading Abilities in Children with Autism Spectrum Disorders.” *Research in Autism Spectrum Disorders* 47(July 2017): 14–25. http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L620326623%0Ahttp://dx.doi.org/10.1016/j.rasd.2017.12.002%0Ahttp://findit.library.jhu.edu/resolve?sid=EMBASE&issn=18780237&id=doi:10.1016%2Fj.rasd.2017

.12.002&atitle=An+analysis+of+r.

Nation, Kate, Paula Clarke, Barry Wright, and Christine Williams. 2006. "Patterns of Reading Ability in Children with Autism Spectrum Disorder." *Journal of Autism and Developmental Disorders* 36(7): 911–19.

National Autism Society of Malaysia. 2018. "What Is Autism?" http://www.nasom.org.my/autism/.

National Autistic Society. 2015. "What Is Autism ?" *The National Autistic Society*. http://www.autism.org.uk/about/what-is.aspx.

National Center for Technology Innovation. 2018. "Speech Recognition for Learning." *National Center for Technology Innovation*: 1–5. http://www.readingrockets.org/article/speech-recognition-learning/.

Neri, Ambra, Catia Cucchiarini, and Helmer Strik. 2001. "Effective Feedback on L2 Pronunciation in ASR-Based CALL." *Computer Assisted Language Learning*.

Neuman, Susan B., Carol Copple, and Bredekamp Sue. 2000. "Learning to Read and Write: Developmentally Appropriate Practices for Young Children." *National Association for the Education of Young Children*: 23, 179–83.

O'Conner, N., and B. Hermelin. 1994. "Two Autistic Savant Readers." 24(4).

O'Connor, Irene M., and Perry D. Klein. 2004. "Exploring of Strategies for Facilitating the Reading Comprehension of High-Functioning Students with Autism Spectrum Disorders." *Journal of Autism and Developmental Disorders* 34(2): 115–27. http://www.aspires-relationships.com/exploration_of_strategies_for_facilitating_the_reading_compreh ension_of_hf_students_with_asd.pdf.

Panyan, Marion V. 1984. “Computer Technology for Autistic Students.” *Journal of Autism and Developmental Disorders* 14(4): 375–82.

Parr, Michelann. 2013. “Text-to-Speech Technology as Inclusive Reading Practice: Changing Perspectives, Overcoming Barriers.” *learning landscapes* 6(2): 303–22.

Parsons, Sarah, and Sue Cobb. 2011. “State-of-the-Art of Virtual Reality Technologies for Children on the Autism Spectrum.” *European Journal of Special Needs Education* 26(3): 355–66.

Pavlov, Nikolay. 2014. “User Interface for People with Autism Spectrum Disorders.” *Journal of Software Engineering and Applications* 07(02): 128–34. http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/jsea.2014.72014.

Peffers, Ken, Tuure Tuunanen, Marcus A. Rothenberger, and Samir Chatterjee. 2007. “A Design Science Research Methodology for Information Systems Research.” *Journal of Management Information Systems* 24(3): 45–77. http://www.tandfonline.com/doi/full/10.2753/MIS0742-1222240302.

Picard, R. W. 2009. “Future Affective Technology for Autism and Emotion Communication.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364(1535): 3575–84. http://rstb.royalsocietypublishing.org/cgi/doi/10.1098/rstb.2009.0143.

Plavnick, Joshua B. et al. 2016. “Mediating Access to Headsprout® Early Reading for Children with Autism Spectrum Disorders.” *Journal of Behavioral Education* 25(3): 357–78. http://link.springer.com/10.1007/s10864-015-9244-x.

Powell, S. 1996. “The Use of Computers in Teaching People with Autism.” *In Autism on the agenda: papers from a National Autistic Society Conference*.

Precoda, Kristin, Christine A Halverson, and Horacio Franco. 2000. “Effects of Speech Recognition-Based Pronunciation Feedback on Second-Language Pronunciation Ability.” *InSTILL 2000*: 102–5.

Quill, K. A. 1997. “Instructional Considerations for Young Children with Autism: The Rationale for Visually Cued Instruction.” *Journal of Autism & Developmental Disorders* 27.6: 697–714.

Ricketts, Jessie. 2011. “Research Review: Reading Comprehension in Developmental Disorders of Language and Communication.” *Journal of child psychology and psychiatry, and allied disciplines* 52(11): 1111–23. http://dx.doi.org/10.1111/j.1469-7610.2011.02438.

Rose, David, and Anne Meyer. 2000. “The Future Is in the Margins : The Role of Technology and Disability in Educational Reform.” *US department of education*.

Rosenthal, Daniel I et al. 1998. “Computer-Based Speech Recognition as a Replacement for Medical Transcription.” (January): 23–25.

Salim, Siti Salwah et al. 2016. “A Speech Pronunciation Practice System for Speech-Impaired Children: A Study to Measure Its Success.” *Research in Developmental Disabilities* 56: 41–59. http://dx.doi.org/10.1016/j.ridd.2016.05.013.

Schlosser, Ralf W., and Doreen M. Blischak. 2004. “Effects of Speech and Print Feedback on Spelling by Children With Autism.” *Journal of Speech Language and Hearing Research* 47(4): 848. http://jslhr.pubs.asha.org/article.aspx?doi=10.1044/1092-4388(2004/063).

Smith, B R, F Spooner, and C L Wood. 2013. “Using Embedded Computer-Assisted Explicit Instruction to Teach Science to Students with Autism Spectrum Disorder.” *Research in Autism Spectrum Disorders* 7(3): 433–43.

Spector, Janet E., and Brian J. Cavanaugh. 2015. “The Conditions of Beginning Reading Instruction for Students With Autism Spectrum Disorder.” *Remedial and Special Education* 36(6): 337–46.

Stern, P., and Lilach Shalev. 2013. “The Role of Sustained Attention and Text’s Conditions in Reading Comprehension among Adolescents with ADHD and without It.” *Research in Developmental Disabilities* 34: 431–439.

Tartaro, Andrea et al. 2014. “Accessing Peer Social Interaction: Using Authorable Virtual Peer Technology As a Component of a Group Social Skills Intervention Program.” *ACM Transactions on Accessible Computing (TACCESS)* 6(1): 1–29. http://doi.acm.org/10.1145/2700434.

Torgesen, Joseph K, Mary D Waters, Andrew L Cohen, and Jeffery L Torgesen. 1988. “Improving Sight-Word Recognition Skills in LD Children: An Evaluation of Three Computer Program Variations.” *Learning Disability Quarterly* 11(2): 125–32.

Vitásková, Kateřina, Lucie Kytnarová, and Jana Mironova Tabachová. “ASSESSMENT OF THE INFLUENCE OF SPEECH-LANGUAGE INTERVENTION ON PERCEPTUAL-SENSORY INTEGRATION IN PERSONS WITH AUTISM SPECTRUM DISORDER IN THE CONTEXT OF ASSESSING THE PRAGMATIC LEVEL OF LANGUAGE.”

Waddington, Hannah et al. 2014. “Three Children with Autism Spectrum Disorder Learn to Perform a Three-Step Communication Sequence Using an IPad ® -Based Speech-

Generating Device." *International Journal of Developmental Neuroscience* 39: 59–67. http://dx.doi.org/10.1016/j.ijdevneu.2014.05.001.

Welch, Karla Conn, Uttama Lahiri, Zachary Warren, and Nilanjan Sarkar. 2010. "An Approach to the Design of Socially Acceptable Robots for Children with Autism Spectrum Disorders." *International Journal of Social Robotics* 2(4): 391–403.

Westerveld, Marleen F., David Trembath, Leanne Shellshear, and Jessica Paynter. 2016. "A Systematic Review of the Literature on Emergent Literacy Skills of Preschool Children With Autism Spectrum Disorder." *Journal of Special Education* 50(1): 37–48.

Whalon, Kelly J., and Juliet E. Hart. 2011. "Children With Autism Spectrum Disorder and Literacy Instruction: An Exploratory Study of Elementary Inclusive Settings." *Remedial and Special Education* 32(3): 243–55.

Wiggins, Lisa D. et al. 2015. "ASD Symptoms among Children." 45(10): 3183–94.

Williams, Susan M, Don Nix, and Peter Fairweather. 2000. "Using Speech Recognition Technology to Enhance Literacy Instruction for Emerging Readers Watch Me ! Read." : 115–20.

Wolk, L., M. L. Edwards, and C. Brennan. 2016. "Phonological Difficulties in Children with Autism: An Overview." *Speech, Language and Hearing* 19(2): 121–29. https://www.tandfonline.com/doi/abs/10.1080/2050571X.2015.1133488?journalCode=yslh20.

Xiong, W. et al. 2018. "The Microsoft 2017 Conversational Speech Recognition System." *ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing - Proceedings* 2018-April(August): 5934–38.

Xuedong Huang et al. 2002. “Microsoft Windows Highly Intelligent Speech Recognizer: Whisper.” : 93–96.

Yaw, Jared S. et al. 2011. “Extending Research on a Computer-Based Sight-Word Reading Intervention to a Student with Autism.” *Journal of Behavioral Education* 20(1): 44–54.

Yoder, D. E. 2001. “Having My Say.” *AAC: Augmentative and Alternative Communication* 17(1): 2–10.

El Zein, Farah, Michael Solis, Sharon Vaughn, and Lisa McCulley. 2014. “Reading Comprehension Interventions for Students with Autism Spectrum Disorders: A Synthesis of Research.” *Journal of Autism and Developmental Disorders* 44(6): 1303–22.

Zhao, Yong. 2007. “Speech Technology and Its Potential for Special Education.” *Special Education Technology* 22(3): 35–41.

Zheng, Zhi et al. 2016. “Brief Report: Evaluation of an Intelligent Learning Environment for Young Children with Autism Spectrum Disorder.” *Journal of Autism and Developmental Disorders* 46(11): 3615–21.

Zinovjeva, Natalia. 2005. “USE OF SPEECH TECHNOLOGY IN LEARNING TO SPEAK A FOREIGN LANGUAGE.” *Speech Technology* (1999): 1–10.