M.Sc. Engg. Thesis

A Computer Mediated Approach for Improving Speaking Skills of the Autistic Children

by
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Candidate's Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Abstract

Speech disorder is one of the most common problems found with the autistic children. The problems related to the speech of the autistic children have a wide range of varieties including non-response, low voice, uttering of irrelevant words, repeating sentences, lack of the sense of turn taking etc. We have made a hierarchy of speaking skills and suggested corresponding games for each stage to achieve necessary level of efficiency. From the observations of the already existing literatures, it is proved that the autistic children pay more attention to the computer screen than to human face. Further, the attention span and intensity are much greater for playing any type of game, rather than watching a non-interactive event. Hence, a motivation toward using this attention to develop certain skills in autistic children was achieved. With that motivation, we address the communication issues of the autistic children and try to improve their socialization process through interactive computer games. Speech, being the prime medium of communication, comes to our attention first. In this thesis, we have developed a number of computer games to develop a better speech of the autistic children. Further, we analysed the speech of the autistic children and automatically detected turns from their speech. The performances of our games were checked against the real dataset developed while working with the children of Autism Welfare Foundation (AWF). Both the quantitative analysis and the qualitative feedback from the parents and the teachers, our games were proved to be an effective tool for helping the autistic children in their speech development.

Chapter 1

Introduction

The Autism Spectrum Disorders (ASD) are defined by the qualitative impairments in social communication. Although the actual reason for autism is still unknown to the medical sciences, it is thought to be the result of abnormal and irregular growth of cerebral structure. The people who suffer from ASD cannot communicate to the other members of the society in usual ways and hence, sometimes become a burben of the family and the nation. The number of people suffering from ASD has been increasing very rapidly in different parts of the world particularly since the second world war. This increasing number has become a big concern both for the psychologists and the physicians. Although a good number of therapies are available for teaching autistic people how to communicate to other people, most of those are not much effective. Furthermore, there has been no empirical or theoretical research framework to address any particular problem related with ASD. As a result the whole autism spectrum has remained under the darkness of mystery over the years.

Autism has a strong genetic basis, although the genetics of autism are complex and it is unclear whether ASD is explained more by rare mutations, or by rare combinations of common genetic variants. In rare cases, autism is strongly associated with agents that cause birth defects. Controversies surround other proposed environmental causes, such as heavy metals, pesticides or childhood vaccines; the vaccine hypotheses are biologically implausible and lack convincing scientific evidence. The prevalence of autism is about 1 per 1,000 people worldwide; however, the Centers for Disease Control and Prevention (CDC) reports approximately 9 per 1,000 children in the United States are diagnosed with ASD [1]. The number of people diagnosed with autism has increased dramatically since the 1980s, partly due to changes in diagnostic practice; the question of whether actual prevalence has increased is unresolved.

1.1 Characteristics

Autism is a highly variable neurodevelopmental disorder that first appears during infancy or childhood, and generally follows a steady course without remission. Overt symptoms gradually begin after the age of six months, become established by age two or three years, and tend to continue through adulthood, although often in more muted form. It is distinguished not by a single symptom, but by a characteristic triad of symptoms: impairments in social interaction; impairments in communication; and restricted interests and repetitive behavior. Other aspects, such as atypical eating, are also common but are not essential for diagnosis. Autism's individual symptoms occur in the general population and appear not to associate highly, without a sharp line separating pathologically severe from common traits.

1.1.1 Social development

Social deficits distinguish autism and the related autism spectrum disorders from other developmental disorders. People with autism have social impairments and often lack the intuition about others that many people take for granted. Noted autistic Temple Grandin described her inability to understand the social communication of neurotypicals, or people with normal neural development, as leaving her feeling *like an anthropologist on Mars*.

Unusual social development becomes apparent early in childhood. Autistic infants show less attention to social stimuli, smile and look at others less often, and respond less to their own name. Autistic toddlers differ more strikingly from social norms; for example, they have less eye contact and turn taking, and do not have the ability to use simple movements to express themselves, such as the deficiency to point at things. Three- to five-year-old autistic children are less likely to exhibit social understanding, approach others spontaneously, imitate and respond to emotions, communicate nonverbally, and take turns with others [3]. However, they do form attachments to their primary caregivers. Most autistic children display moderately less attachment security than non-autistic children, although this difference disappears in children with higher mental development or less severe ASD. Older children and adults with ASD perform worse on tests of face and emotion recognition [8].

Children with high-functioning autism suffer from more intense and frequent loneliness compared to non-autistic peers, despite the common belief that children with autism prefer to be alone. Making and maintaining friendships often proves to be difficult for those with autism. For them, the quality of friendships, not the number of friends, predicts how lonely they feel. Functional friendships, such as those resulting in invitations to parties, may affect the quality of life more deeply [2].

There are many anecdotal reports, but few systematic studies, of aggression and violence in individuals with ASD. The limited data suggest that, in children with mental retardation, autism is associated with aggression, destruction of property, and tantrums. A 2007 study interviewed parents of 67 children with ASD and reported that about two-thirds of the children had periods of severe tantrums and about one-third had a history of aggression, with tantrums significantly more common than in non-autistic children with language impairments [2]. A 2008 Swedish study found that, of individuals aged 15 or older discharged from hospital with a diagnosis of ASD, those who committed violent crimes were significantly more likely to have other psychopathological conditions such as psychosis [3].

1.1.2 Communication

About a third to a half of individuals with autism do not develop enough natural speech to meet their daily communication needs. Differences in communication may be present from the first year of life, and may include delayed onset of babbling, unusual gestures, diminished responsiveness, and vocal patterns that are not synchronized with the caregiver. In the second and third years, autistic children have less frequent and less diverse babbling, consonants, words, and word combinations; their gestures are less often integrated with words. Autistic children are less likely to make requests or share experiences, and are more likely to simply repeat others' words (echolalia) or reverse pronouns. Joint attention seems to be necessary for functional speech, and deficits in joint attention seem to distinguish infants with ASD: for example, they may look at a pointing hand instead of the pointed-at object, and they consistently fail to point at objects in order to comment on or share an experience. Autistic children may have difficulty with imaginative play and with developing symbols into language [4].

In a pair of studies, high-functioning autistic children aged 817 performed equally well as, and adults better than, individually matched controls at basic language tasks involving vocabulary and spelling. Both autistic groups performed worse than controls at complex language tasks such as figurative language, comprehension and inference. As people are often sized up initially from their basic language skills, these studies suggest that people speaking to autistic individuals are more likely to overestimate what their audience comprehends [4-5].

1.1.3 Repetitive behavior

Autistic individuals display many forms of repetitive or restricted behavior, which the Repetitive Behavior Scale-Revised (RBS-R) categorizes as follows.

1. **Stereotypy** is repetitive movement, such as hand flapping, making sounds, head

rolling, or body rocking.

2. **Compulsive behavior** is intended and appears to follow rules, such as arranging objects in stacks or lines.

3. **Sameness** is resistance to change; for example, insisting that the furniture not be moved or refusing to be interrupted.

4. **Ritualistic behavior** involves an unvarying pattern of daily activities, such as an unchanging menu or a dressing ritual. This is closely associated with sameness and an independent validation has suggested combining the two factors.

5. **Restricted behavior** is limited in focus, interest, or activity, such as preoccupation with a single television program, toy, or game.

6. **Self-injury** includes movements that injure or can injure the person, such as eye poking, skin picking, hand biting, and head banging. A 2007 study reported that self-injury at some point affected about 30% of children with ASD [2].

No single repetitive or self-injurious behavior seems to be specific to autism, but only autism appears to have an elevated pattern of occurrence and severity of these behaviors.

1.1.4 Other symptoms

Autistic individuals may have symptoms that are independent of the diagnosis, but that can affect the individual or the family. An estimated 0.5% to 10% of individuals with ASD show unusual abilities, ranging from splinter skills such as the memorization of trivia to the extraordinarily rare talents of prodigious autistic savants. Many individuals with ASD show superior skills in perception and attention, relative to the general population. Sensory abnormalities are found in over 90% of those with autism, and are considered core features by some, although there is no good evidence that sensory symptoms differentiate autism from other developmental disorders. Differences are greater for under-responsivity (for example, walking into things) than for over-responsivity (for example, distress from loud noises) or for sensation seeking (for example, rhythmic movements). An estimated 60% to 80% of autistic people have motor signs that include poor muscle tone, poor motor planning, and toe walking; deficits in motor coordination are pervasive across ASD and are greater in autism proper [19].

Unusual eating behavior occurs in about three-quarters of children with ASD, to the extent that it was formerly a diagnostic indicator. Selectivity is the most common problem, although eating rituals and food refusal also occur; this does not appear to result in malnutrition. Although some children with autism also have gastrointestinal (GI) symptoms, there is a lack of published rigorous data to support the theory that autistic children have more or different GI symptoms than usual; studies report conflicting results, and the relationship between GI problems and ASD is unclear [12].

1.2 Classification

Autism is one of the five Pervasive Developmental Disorders (PDD), which are characterized by widespread abnormalities of social interactions and communication, and severely restricted interests and highly repetitive behavior. These symptoms do not imply sickness, fragility, or emotional disturbance.

Of the five PDD forms, Asperger syndrome is closest to autism in signs and likely causes; Rett syndrome and childhood disintegrative disorder share several signs with autism, but may have unrelated causes; PDD not otherwise specified (PDD-NOS; also called atypical autism) is diagnosed when the criteria are not met for a more specific disorder. Unlike with autism, people with Asperger syndrome have no substantial delay in language development. The terminology of autism can be bewildering, with autism, Asperger syndrome and PDD-NOS often called the autism spectrum disorders (ASD) or sometimes the autistic disorders, whereas autism itself is often called autistic disorder, childhood autism, or infantile autism. In this article, autism refers to the classic autistic disorder; in clinical practice, though, autism, ASD, and PDD are often used interchangeably. ASD, in turn, is a subset of the broader autism phenotype, which describes individuals who may not have ASD but do have autistic-like traits, such as avoiding eye contact [19].

The manifestations of autism cover a wide spectrum, ranging from individuals with severe impairments who may be silent, mentally disabled, and locked into hand flapping and rocking to high functioning individuals who may have active but distinctly odd social approaches, narrowly focused interests, and verbose, pedantic communication. Because the behavior spectrum is continuous, boundaries between diagnostic categories are necessarily somewhat arbitrary. Sometimes the syndrome is divided into low-, medium- or high-functioning autism (LFA, MFA, and HFA), based on IQ thresholds, or on how much support the individual requires in daily life; these subdivisions are not standardized and are controversial. Autism can also be divided into syndromal and non-syndromal autism; the syndromal autism is associated with severe or profound mental retardation or a congenital syndrome with physical symptoms, such as tuberous sclerosis. Although individuals with Asperger syndrome tend to perform better cognitively than those with autism, the extent of the overlap between Asperger syndrome, HFA, and non-syndromal autism is unclear [8].

Some studies have reported diagnoses of autism in children due to a loss of language or social skills, as opposed to a failure to make progress, typically from 15 to 30 months of age. The validity of this distinction remains controversial; it is possible that regressive autism is a specific subtype, or that there is a continuum of behaviors between autism with and without regression.

Research into causes has been hampered by the inability to identify biologically meaningful subpopulations and by the traditional boundaries between the disciplines of psychiatry, psychology, neurology and pediatrics. Newer technologies such as MRI and diffusion tensor imaging can help identify biologically relevant phenotypes (observable traits) that can be viewed on brain scans, to help further neurogenetic studies of autism; one example is lowered activity in the fusiform face area of the brain, which is associated with impaired perception of people versus objects. It has been proposed to classify autism using genetics as well as behavior [7].

1.3 Causes

It has long been presumed that there is a common cause at the genetic, cognitive, and neural levels for autism's characteristic triad of symptoms. However, there is increasing suspicion that autism is instead a complex disorder whose core aspects have distinct causes that often co-occur.

Autism has a strong genetic basis, although the genetics of autism are complex and it is unclear whether ASD is explained more by rare mutations with major effects, or by rare multigene interactions of common genetic variants. Complexity arises due to interactions among multiple genes, the environment, and epigenetic factors which do not change DNA but are heritable and influence gene expression. Studies of twins suggest that heritability is 0.7 for autism and as high as 0.9 for ASD, and siblings of those with autism are about 25 times more likely to be autistic than the general population. However, most of the mutations that increase autism risk have not been identified. Typically, autism cannot be traced to a Mendelian (single-gene) mutation or to a single chromosome abnormality like fragile X syndrome, and none of the genetic syndromes associated with ASDs have been shown to selectively cause ASD. Numerous candidate genes have been located, with only small effects attributable to any particular gene. The large number of autistic individuals with unaffected family members may result from copy number variations by spontaneous deletions or duplications in genetic material during meiosis. Hence, a substantial fraction of autism cases may be traceable to genetic causes that are highly heritable but not inherited: that is, the mutation that causes the autism is not present in the parental genome [15].

1.4 Speech of Autistic Children

Several lines of evidence point to synaptic dysfunction as a cause of autism. Some rare mutations may lead to autism by disrupting some synaptic pathways, such as those involved with cell adhesion. Gene replacement studies in mice suggest that autistic symptoms are closely related to later developmental steps that depend on activity in synapses and on activity-dependent changes. All known teratogens (agents that cause birth defects) related to the risk of autism appear to act during the first eight weeks from conception, and though this does not exclude the possibility that autism can be initiated or affected later, it is strong evidence that autism arises very early in development.

Although evidence for other environmental causes is anecdotal and has not been confirmed by reliable studies, extensive searches are underway. Environmental factors that have been claimed to contribute to or exacerbate autism, or may be important in future research, include certain foods, infectious disease, heavy metals, solvents, diesel exhaust, PCBs, phthalates and phenols used in plastic products, pesticides, brominated flame retardants, alcohol, smoking, illicit drugs, vaccines, and prenatal stress, although no links have been found, and some have been completely dis-proven [14].

Parents may first become aware of autistic symptoms in their child around the time of a routine vaccination. This has led to unsupported theories blaming vaccine overload, a vaccine preservative or the MMR vaccine for causing autism.The latter theory was supported by litigation-funded study that has since been shown to have been an elaborate fraud. Although these theories lack convincing scientific evidence and are biologically implausible, parental concern about a potential vaccine link with autism has led to lower rates of childhood immunizations, outbreaks of previously-controlled childhood diseases in some countries, and the preventable deaths of several children.

Parents of children with ASD have higher levels of stress. Siblings of children with ASD report greater admiration of and less conflict with the affected sibling than siblings of unaffected children or those with Down syndrome; siblings of individuals with ASD have greater risk of negative well-being and poorer sibling relationships as adults.

Parents usually notice signs in the first two years of their child's life. The signs usually develop gradually, but some autistic children first develop more normally and then regress. Early behavioral or cognitive intervention can help autistic children gain self-care, social, and communication skills. Although there is no known cure, there have been reported cases of children who recovered. Not many children with autism live independently after reaching adulthood, though some become successful. An autistic culture has developed, with some individuals seeking a cure and others believing autism should be accepted as a difference and not treated as a disorder.

People suffering from autism very often demonstrate a poor performance in social interactions; and hence find it difficult to communicate to other people. On the other hand, it is equally difficult for others to communicate to them in the usual ways. As the number of autistic children has been reported to increase at a high rate throughout the world in recent decades, it has become necessary to discover effective ways for communicating to them. One of the bigger challenges is to ensure good education to the autistic children in a proper way so that they can develop their skills and contribute to the society being within their limitations.

Although the actual reasons for the speech and language problems in autism are still unknown, many experts believe that the difficulties are caused by a variety of conditions that occur either before, during or after the birth effecting cerebral development. This interferes with an individual's ability to interpret and interact with the world while communicating. Different types of irregularities in speech communication have been addressed in literature including the followings:

- *Non-Response*: There are children with ASD who don not respond to the questions they are asked. This type of problem is called as non-response. Although this problem is not directly related to the speech problem, yet we include this as a speech problem associated with ASD. This limitations tells upon their capabilities in communicating to other people of the society.

- *Making Low Sounds in Response*: There are some autistic children, who although respond, make very low sound. So, it becomes difficult for audience to understand what s/he actually said.

- *Making Unintelligible Sounds*: Children who suffer from this problem can loud sound is response to the questions they are asked, but cannot make it clear to the audience. Very often their speech is garbled. Sometimes it is so unintelligible that it seems to be non-human sounds.

- *Making Delay in Answering Questions*: This problem causes the children to make delay in their responses. This delay might be caused by their cognitive limitation or for some other reasons. Sometimes they make such a delay that the audience lose patience.

- *Answering Incorrectly with Articulate Words*: This is again a problem not directly related to speech but somehow effects the verbal communication. Children with this problem make clear intelligible and loud answers, although those answers are not correct logically.

- *Difficulties in Making Correct Sentences with words*: Children with this problem can utter a single words clearly while uttering that separately. However, they struggle in making a complete sentence with more than one words, hence they cannot talk with full speech to the audience.

- *Lacking the Sense of Turn Taking*: This is a commonplace with autistic children that they do not get the invisible social clue of when to start and when to stop talking during a conversation. This problem turns serious with the progress of time and sometimes they dont stop talking once started.

1.5 Objective of The Thesis

Actually, there is no definite treatment for autism. The best we can do is to help the autistic children in making proper social communication being within their limitations. Computer games have recently been proved to be very powerful tools in this regard [5-6]. By exploiting the interest of the autistic children to get rewards in the games, we have tried to develop their skills in speech. In our experiment, with a good number of children over 1 year at Autism Welfare Foundation (AWF) at Dhaka, this approach was proved to be fruitful.

We were motivated to address the speech problems of the autistic children by computer games. The motivation was boosted by the recent finding that autistic children spend more time and give more concentration to television or computer screen other than human faces or text-book. Anything moving, animated and alive makes them feel better. With this, we wanted to make the whole thing inter-active. It is worth-mentioning that a number of computer aided materials are commerciallya available in the market which also offer some games and animation targeted for different classes of children for their learning purposes. We have distinct differences from those in two clear points: 1) our games are inter-active which give the children the sense of the presence of another lively object with them, 2) our games are customizable which is very much needed for the autistic childrne who need extreme level of personalization for their learning environment. For this two reasons, we believe, our games are unique and the first ever attempt to make the children feel better and an effective way of engaging them toward practising.

First, we developed an easy customizable game for the autistic children which help them in increasing the volume of their speech. In this game the speed of an object was interfaced with the voice level of the participant so that the louder she shouted the faster that object would move. This game was developed with the open-source game making platform of MIT Media Lab, called Scratch. We got an overwhelming response from the participants while running a pilot at Autism Welfare Foundation (AWF).

Later, we developed a game which motivated the player to utter clearly to win. Here we used the natural language recognition engine of Microsoft to identify if the participant could utter a word clearly or not. With every intelligible pronunciation, the participant would get some prizes in the game. However, some immediate limitations of this game popped up with its subsequent runs with larger audience. The reasons mainly involved the participants' wide range of vocabulary to define a single object and in some cases, uttering different correct answers. So, it was needed to introduce a human judge in the system to make the judgement clear. But the presence of a human being in the setup would make the participant feel less engaging to himself.

However, in the extension of this game we incorporated human intervention to solve some problems associated with completely automated computer judgement for the game. This was done in a way that the participant got no clue that a human judge is actually judging her responses. With the introduction of human judge the system started to work better.

Our next approach was to increase the fluency in the speech of the autistic children by interactive computer game. We involved the time factor to make the children utter more words quickly and make sentences. In a small time frame we pushed the participant to make more words correctly. We made simple sentences with a number of easy words and displayed the whole sentences with the help of the images of those particular objects sequentially. This could help the children make full sentences seamlessly.

Finally, we make games for turn-taking. By turn-taking, we actually mean the ability to understand when to start talking and when to stop in a conversation. In our game, we used the size of the characters which represented the players to indicate their turns. The motivation was to exploit the natural human nature to respond against the bigger object projected before him/her. Thus we taught them when to react and when not.

All of our games were very much successful when we tested those with the participants of AWF. In all of our experiments, we included the performances for the children who used the games and who did not use those. Then compared their performances over 4 weeks or so. We also measured their performances in social life after applying this game therapy upon them. In all the cases, our games were proved to be effective.

However, we do not suggest to replace the traditional therapies by our game therapies; rather we recommend to introduce our games besides the traditional therapies for the best output.

1.6 Thesis Organization

The thesis is organized as follows. In the second chapter, we first discuss the related works about ASD. Then in the third chapter, we demonstrate our first interactive e-learning games for increasing intelligibility of the autistic children with its software architecture and hardware and software requirements. We talk about the experimental results which prove its success in game therapy. Then in the fourth chapter, we discuss our next computer game which helps children to develop fluency in their speech. Chapter 5 describes our game on increasing the fluency of the autistic children by interactive computer game. In the same chapter, we also analyzed how to detect turn automatically using speech analysis. We conclude with ideas for future works in conclusion.

This whole thesis work is done with the motivation to stand beside the portion of our society who often left alone. We tried our best to help those children who cannot flourish their potential due to their social limitations. We tried to give these tools to those parents who drop silent tears behind the big crowd of the happy parents of the neurotypicals.

Chapter 2

Related Works

2.1 Early History

A few examples of autistic symptoms and treatments were described long before autism was named. The Table Talk of Martin Luther, compiled by his notetaker, Mathesius, contains the story of a 12-year-old boy who may have been severely autistic [4]. Luther reportedly thought the boy was a soulless mass of flesh possessed by the devil, and suggested that he be suffocated, although a later critic has cast doubt on the veracity of this report. The earliest well-documented case of autism is that of Hugh Blair of Borgue, as detailed in a 1747 court case in which his brother successfully petitioned to annul Blair's marriage to gain Blair's inheritance. The Wild Boy of Aveyron, a feral child caught in 1798, showed several signs of autism; the medical student Jean Itard treated him with a behavioral program designed to help him form social attachments and to induce speech via imitation [6].

The New Latin word autismus (English translation autism) was coined by the Swiss psychiatrist Eugen Bleuler in 1910 as he was defining symptoms of schizophrenia. He derived it from the Greek word auts (meaning self), and used it to mean morbid self-admiration, referring to autistic withdrawal of the patient to his fantasies, against which any influence from outside becomes an intolerable disturbance [7].

2.2 Developing the Concept

The word autism first took its modern sense in 1938 when Hans Asperger of the Vienna University Hospital adopted Bleuler's terminology autistic psychopaths in a lecture in German about child psychology. Asperger was investigating an ASD now known as Asperger syndrome, though for various reasons it was not widely recognized as a separate diagnosis until 1981. Leo Kanner of the Johns Hopkins Hospital first used autism in its modern sense in English when he introduced the label early infantile autism in a 1943 report of 11 children with striking behavioral similarities. Almost all the characteristics described in Kanner's first paper on the subject, notably autistic aloneness and insistence on sameness, are still regarded as typical of the autistic spectrum of disorders. It is not known whether Kanner derived the term independently of Asperger [9].

Kanner's reuse of autism led to decades of confused terminology like infantile schizophrenia, and child psychiatry's focus on maternal deprivation led to misconceptions of autism as an infant's response to refrigerator mothers. Starting in the late 1960s autism was established as a separate syndrome by demonstrating that it is lifelong, distinguishing it from mental retardation and schizophrenia and from other developmental disorders, and demonstrating the benefits of involving parents in active programs of therapy. As late as the mid-1970s there was little evidence of a genetic role in autism; now it is thought to be one of the most heritable of all psychiatric conditions. Although the rise of parent organizations and the destigmatization of childhood ASD have deeply affected how we view ASD, parents continue to feel social stigma in situations where their autistic children's behaviors are perceived negatively by others, and many primary care physicians and medical specialists still express some beliefs consistent with outdated autism research [10].

2.3 Research on the Attributes of Autism

Hopkins and Lord's (1981) study showed clearly that autistic children do take account of other people's behavior [3]. This was also found by Sussman and Sklar (1969) and Clark and Rutter (1981) who found differential social responsiveness to varied tone of voice and amount of interpersonal demands, respectively [4]. These latter two studies measured social behavior in terms of degree of compliance, and this is obviously only a small part of social skills. Few papers have given much space to discussion of the definition of social behavior, and this has led to rather crude measures being used. For example, McHale (1983) scored children as part of a group "if they were judged to be within 5 feet of one another, or were playing on or with the same toy" [4]. Clearly however, neither physical proximity nor action on someone else's toy necessarily involves social behavior. The definition of what constitutes social behavior requires a separate paper in itself and cannot be discussed here, but it is worth noting that, in the literature on normal child development, one way in which social behavior has been discussed more thoroughly is in terms of "mutually intentional relations" (Damon, 1979; Frye, 1981). This approach has recently been applied to autism by Mundy, Sig- man, Ungerer, and Sherman (1986), Sigman, Mundy, Sherman, and Un- gerer (1986), and Loveland and Landry (1986) who found that autistic children showed significantly less "joint attention" than matched controls, and "showed" or pointed to toys less often [19].

The Internet has helped autistic individuals bypass nonverbal cues and emotional sharing that they find so hard to deal with, and has given them a way to form online communities and work remotely. Sociological and cultural aspects of autism have developed: some in the community seek a cure, while others believe that autism is simply another way of being [11].

2.4 Research on the Education of Autistic Children

The research for teaching autistic children is not new. In the 1960s, Ivar Lovaas began teaching children with autism new behaviors through a technique called “applied behavior analysis”, in which a behavior is encouraged or discouraged as it encounters environmental consequences. In short, his technique relies upon using objects, foods, and actions as rewards for desired behavior (prompted by a researcher) [9], [13]. Over many trials and sessions, children with autism eventually learn to respond in a predictable fashion by interacting with people in their environment. There are three main drawbacks of this form of treatment:

- It requires many sessions with trained professionals who are in short supply. This can place a financial burden on the family.
- Teaching sessions require intense attention and prolonged contact from a practitioner or parent.
- The child must interact with a human being. One characteristic of ASD is anxious, detached, and ”alone” interaction with other individuals [1], [4]. Thus the interaction with a human being, as the primary mode of teaching, might pose some degree of built-in difficulty for the ASD child.

Some of the existing works have approached ASD from three primary directions. Works by Abowd and others have explored the benefits of technology to aid the diagnosis process [3-7]. This research is crucial, because early detection allows children to begin treatment earlier, allowing them to catch up faster to their non-autistic peers. Further, this work allows us to better understand how to identify autistic characteristics. Although greatly beneficial, this research does not provide a direct method to enhance the education of children with ASD.

Researchers have also explored the effect that technological environments have had on the process of assisting children with autism to learn how to interact with other human beings [5], [15]. This work uses virtual environments, as well as virtual peers, to create situations in which the children with ASD are comfortable. They are then able to learn person-to-person interactions, without the apprehension of having another person in the room . This work, however, primarily has dealt with "high functioning" children, or those who already know how to speak and have a deficit in social interaction. Therefore, it is hoped that principles learned from this body of literature will have the potential to be applied to research targeting children with ASD who have not yet acquired speech.

The third approach seeks to encourage children with ASD to "play", where playing is mediated through technology [8],[10],[14]. By creating technological methods of interaction (visual displays and physical robots), play and comfortable interactions can be garnered from children with autism. There is a feeling of "safety" by having the main form of interaction occur with non-humans. Further, these devices allow the child, rather than a third party, to be in control of the interactions. This research has much potential. To date, however, it has not focused on encouraging more communication-based activities, such as speech and human-to-human interaction.

2.5 Introducing Technology to Autism Research

Among interesting interactive robotic systems are the *KISMET* platform [4] and the *ROBOTA* dolls [2], [3]. *KISMET* is a humanoid face that can generate expressive social interactions with human caretakers. Such meaningful interactions can be regarded as a tool for development of social relationships between a robot and a human. The *ROBOTA* dolls are humanoid robots developed as interactive toys for children and are used as research platforms in order to study how a human can teach a robot, using imitation, speech and gestures. Increasingly, robotic platforms are developed as interactive playmates for children [5], [16]. Besides commercial purposes (see Sonys *Aibo* robot), such interactive robotic systems can potentially be utilized as learning environments and in rehabilitation applications, as studied in the *AURORA* project [1].

2.6 Discussion

All the previous works done before are mainly based on human effort which was proved to be not much effective if the child is not attracted to the person who tries to convey the therapy. The videos found on CDs or DVDs are not also effective as those are not interactive. Then cannot hold the attention of the children for a longer period of time. The games made for the normal children are not also fruitful for the autistic children as those need more matured cognitive maturity. The robots developed int his purpose are quite expensive and hence, not yet at the reach of the general mass. Hence, it was needed to make specialized games for the autistic children which are attractive and effective at the same time and have been specially made for them.

Chapter 3

Proposed Speech Disorder Hierarchy

3.1 Observations

Autistic children, in general, do not concentrate into a particular subject for a long. So, it is difficult to teach them anything. They only concentrate into the objects they get interest in. Most of the times, they get the traditional teaching tools not much attractive and hence, it becomes difficult for the teachers to teach them. From our experiences, we could understand that most of the autistic children are very much interested in computer games. So, here we used interactive computer games to develop their speech. The main idea of this thesis is to keep their interest and concentration in computer games and teach them necessary things by those.

From our observation, we could find that the problems of autistic children have a wide range of variety and it is almost impossible to design a single game for a group of children. Instead, each child needs to be treated individually. Hence, we are suggesting different types of games with different variation for different problems here.

3.2 Proposed Speech Disorder Hierarchy

For our intervention, we designed a speech disorder hierarchy for autistic children. This hierarchy is made upon our experiences we had while working with autistic children. Here are the stages:

3.2.1 Stage 1: Non Response

Children at this stage do not respond verbally to any question. Some children respond non-verbally by making some physical gestures, eye contacts etc. while some of them remain completely unmoved in response to a question thrown at them. After investigation, we could determine some of the possible reasons why autistic children at this stage do not respond verbally. They are as follows:

- They do not realize that a question has been thrown at them. This can be the result of their hearing imparity or inability to distinguish a question from other sentences.
- They do not know that they need to respond if a question is thrown at them.
- They do not feel that they have to answer the question. Sometimes they wait for other people to answer the question.
- They do not know what to answer. This may happen when they do not know the answer or cannot understand the question.
- They feel shy to answer.
- They prefer non-verbal ways of responding to talking.
- They do not find the answering task interesting.
- They cannot keep their concentration into the subject matter for a period of time.

3.2.2 Stage 2: Making Low Sounds in Response

Children at this stage make some low sounds in response to a question. Most of the time, the sounds they produce are meaningless and those are too low to be heard by the audience. Children at this stage are expected not suffering from the problems of stage 1. That is, they can recognize if a question is asked to them. They know that they have to answer it verbally and they do not feel shy to answer them. But they do not make loud sounds in reply. We could identify some reasons why they do not produce loud sounds. They are as follows:

- They have problems in their oral structure and they cannot produce loud sounds because of this limitation. We have to remember that many of the autistic children suffer from other physical disabilities, too.
- They do not get enough motivation to produce loud sounds.
- They hate loud sounds
- They think loud sounds are made for special reasons only, such as, calling someone, rebuking somebody etc.

3.2.3 Stage 3: Making Unintelligible Sounds

Children at this stage can generally produce loud sounds in reply of a question, but the sounds they make are not intelligible. Although those are loud enough to be heard, the audience cannot get the meaning of those. Sometimes those seem to be the distorted forms of the answers but sometimes nothing can be assumed from those. We have found some reasons why this problem takes place:

- This problem may be the result of the distortion of their oral structure. They cannot produce articulate words because of this limitation although they know the actual pronunciations.

- They do not know the actual pronunciations.
- They do not get the motivation to utter the words clearly; rather they just try to finish answering quickly. They do not get it interesting to answer the questions with articulate words.
- They do not feel that uttering clearly is actually necessary.

3.2.4 Stage 4: Making Delay in Answering Questions

At this stage, the autistic children take too much time in replying to a question. After getting the question they begin to think about it. After taking a long period (ranging from 5 seconds to 50 seconds) of time, they make the answer or simply do not respond if the answer is not known to them. We could find out a reason for this type of delay. That is:

- Their cognitive ability is not fast enough to respond to a question quickly. It takes time to analyze the question and get what is asked in the question. Then they start searching in their memory for the answer. If they get any answer, they reply, otherwise they just continue searching. For weak cognitive power, their searching process is slower than the normal human being. As a result, the make this delay. By experimenting with different type of questions, it was clear that many of them memorize the answers by visualization or audio clues. If we tell them the answer once and ask the same question, they take less time to answer it. But if we ask the same question in different way, it takes more time for them to answer.
- Poor vocabulary is another reason why sometimes autistic people make delay in responding. Due to a limited vocabulary, they often need to search hard in to get the appropriate word to respond. This also happens with a normal being with foreign language, but the autistic children often get it even for their native languages.

3.2.5 Stage 5: Answering Incorrectly with Articulate Words

At this stage the autistic children answer any question thrown at them, but their answers are not correct. They make answers to almost all the questions with loud and articulate words, but the answers are not correct although they know the correct answer. Very often they are found to make irrelevant statements or repeating the question. We could chalk out some causes behind this:

- They are not capable of making the answers. Many of the autistic children are not capable of bearing the cognitive load of answering a question or it takes them too much time. But when they feel that they have to answer the question quickly, they just start saying whatever they get. Most of the time they repeat the question.
- They look for the answers around them and expect someone to help them in answering.
- Sometimes they feel that answering the questions is a good thing and they do not need to be correct.
- They do not get the motivation to make the correct answer.

3.2.6 Stage 6: Difficulties in Making Correct Sentences with Words

At this stage the autistic children can respond with correct words articulately, but they get it difficult to make a complete sentence with the words. Varieties of problems were found with the children at this stage. For example:

- Some of them cannot use proper possessive words for themselves. They do not use "I" or "mine". Instead, they use their names.
- Some of them cannot use the proper form of verbs.

- Some of them cannot combine the nouns and verbs properly.
- Some of them have problems with tense

3.2.7 Stage 7: Lacking the Sense of Turn Taking

By turn taking, we mean understanding and responding to the turns in group activities, such as conversation or playing with others. For example, when two or more people make a conversation, one of them talks while others listen. Then s/he stops talking and another person starts talking. It is important to understand when one should start talking and how long s/he should talk. Similarly, in playing games or in some other group activities, this sense is important for a child for being social. Many of the autistic children do not have this sense. They cannot recognize when they should start talking and when they should stop. We could find out some reasons why they do not take necessary turns. They are:

- An autistic child suffering from the lacking of the sense of turn-taking does not understand that there are more people like him/her around. S/he either thinks all the things happen around him/her are only for him/her or thinks none of them are for him/her.
- They do not have the patience in them to wait for their turn.
- They do not find the taking turn an interesting thing; rather they consider it as a sacrifice that they do not like.

3.3 Discussion

This hierarchy ensures the clear and audible speech by the participant, no matter if the answer is correct or not. In our research one of the primary assumption is that the difficulties that the children face while talking is the sole outcome of their mental barrier and not caused by their physical disabilities. However, while discovering if a child has any physical disability, our speech therapies can be used. A negative result as the output of our therapy might mean that the child is suffering from any physical problem for which s/he is not being able to overcome the difficulties of the speech.

Chapter 4

Improving Intelligibility

In this section we present the overview of and the architecture of the game, and our implementation procedure with software and hardware requirements for the problem of *Making Unintelligible Sounds*.

4.1 Overview of the Interactive Game

The game we developed is an interactive e-learning game in which an autistic child who makes unintelligible sounds will try to produce clear words to communicate to the computer. The basic idea of this game is very simple. Various kinds of interesting pictures appear in the Graphical User Interface (GUI) as shown in the Figure 1(a) one by one and the autistic child who can pronounce the name of the picture clearly and loudly can score and win the game. As a result the autistic child will try to make clear and loud pronunciation to win the game which in turn helps them to overcome their unintelligibility problem. While selecting images we emphasized on the familiarity of the objects to the autistic children. We also set the word for each of these images based on their familiarity to avoid the possible problem regarding synonyms. Besides, there are provision for extending this game for others language and themes.

(a)Main Game Scene 1 (b)Main Game Scence 2 (c)Winning Stage

Figure 4.1: An example of the interactive game

In Figure 4.1, we illustrate a simple example of this game. For example, after running the game, the main game window [shown in figure. 1(a)] appears. We must make sure the microphone is ready. The Speech Recognition engine is automatically started. Now the speech engine is ready to detect desired word as shown in the figure. There is a timer which keeps track of time. Every image is given some fixed time to be uttered. After this time the uttered word is matched with the correct word. If the word is correctly pronounced the student will get points and in this way the game proceeds. If the word does not match with the word specified in the XML grammar file, she will not get any point and next image will be shown. There is a set of images and the game concludes if all the images are successfully uttered. Finally after winning the game a dialogue window will come as shown in the Figure. 1(c) and it also makes sound "Wow, you won!"

4.1.1 The Architecture of the game

The game has been made with very simple technologies. The initial version fo the game was made with Microsoft .NET platform. The central idea of the game consists of a picture database where we put all the photos of the children which they are familiar with. Then we build a corresponding dictionary of words each connected to one or more pictures of the picture database. For catching the voice of the participant's we used general microphones, although we believe a better result could be achieved if we could use the noise free spohisticated ones. But considering the scalability of the game toward the low-income population, we decided to use the cheaper microphones with a certain range of error. We developed our games in Microsoft Windows environment with Microsoft .NET Framework. We used the default speech recognition engine of .NET which is pluggable to the application via DLL files. The core of the game consists of the following part.

- Engine at the back end for speech recognition.
- XML grammar files containing the grammar of the specific words.
- Graphical User Interface at the front end for communication.

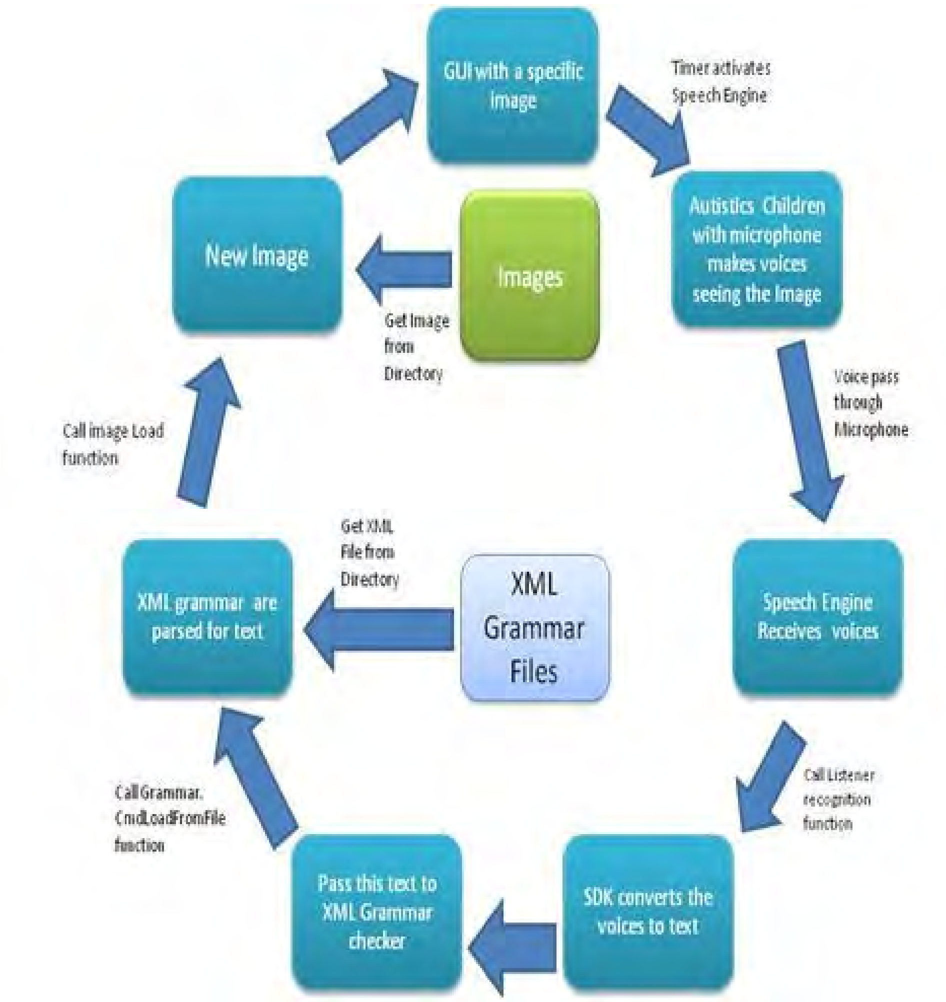

Figure 4.2: Data Flow Diagram

Figure 4.2 represents the data flow diagram of our interactive game. At the beginning a GUI appears with specific image. Next an autistic child with microphone makes voice or pronounces the name of the picture [shown in figure. 4.1(b)] which passes through the microphone to the Speech Engine. When times out the last saved word of the child is passed to an internal procedure that converts it as text. Now this word is passed to the grammar checker function which in turn calls another internal procedure that loads the XML Grammar File from directory. Then this XML Grammar File is parsed for that specific word. Finally another image is loaded from the directory by another internal procedure which is shown in Graphical User Interface (GUI). And in this way the data flow continues in the game.

To implement Speech Engine for speech recognition we have used Microsoft Speech Engine for English Speech SDK 5.1, Microsoft .NET Framework 3.5. We have used Microsoft visual studio 2008 for graphical user interface (GUI) purpose. For Operating System we have used Microsoft Windows XP service pack 2.

4.2 Experimental Results

For autistic children those who made unintelligible sound, we have found that following level-wise experiment is very effective. Since in "English Language" most of the words are monosyllable, disyllable or trisyllable we divided the experiment into three distinctive sessions which we called levels. For the sake of simplicity and ease of discussion, all the chart and graph we have provided in the following experiment considering only one autistic child.

4.2.1 Level 1: Monosyllabic Words with Unlimited Number of Attempts

We started our experiment with monosyllabic words. At this early stage of the experiment an autistic child would get unlimited opportunity to pronounce the word correctly. No matter how many attempts they took, they would get rewards. The results are shown in Figure 4.3 and 4.4. From these figures, it is clearly understandable that the gradual progress of the children who use computer games is much better than the other therapies commonly found in the communities.

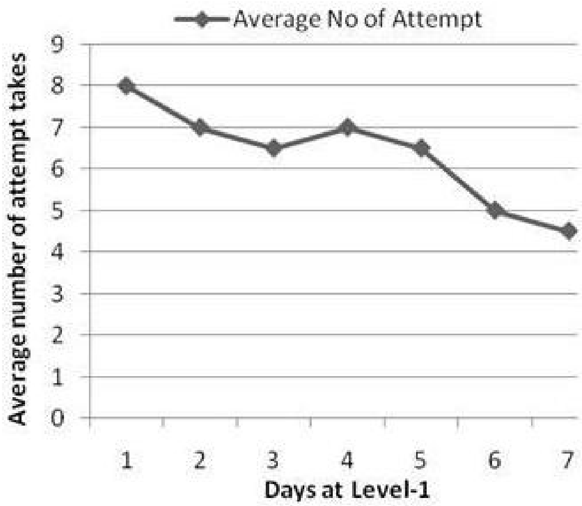

Figure 4.3: Average Number of attempt takes

4.2.2 Level-2: Monosyllabic and Disyllabic Words with Fixed Number of Attempts

After successfully completing the level-1 experiment these autistic children were taught to pronounce both mono-syllabic and di-syllabic words. However at this stage of the experiment they would get only a fixed number of chances. If they could do it within the limits it was considered as a success otherwise it was failure.

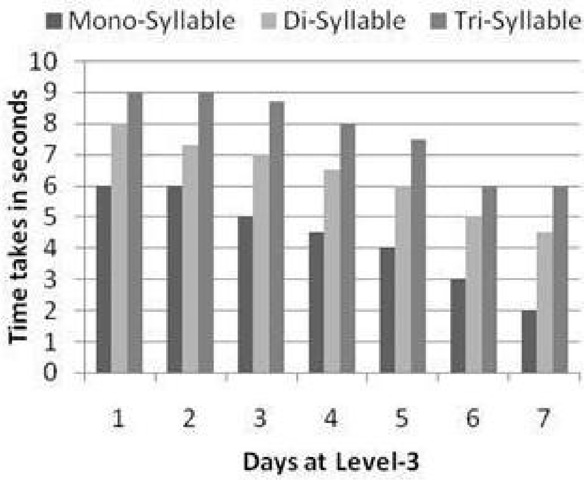

Figure 4.4: An autistic child's promptness at Level-3

4.2.3 Level-3: Mono, Di and Trisyllabic Words with Fast Responses

Since at this stage, the autistic children were familiar with both mono and di-syllabic words, so we tried to increase the speed of their speech.

Figure 4.5: An overall performance of an autistic child

For computing the effectiveness we counted how fast an autistic children response with the image and correctly. Based on this analytical reports [shown in Figure. 4.3, 4.4 and 4.5] generated by our software a teacher decides which child is making improvement or who needs further assistance.

4.3 Discussion

The above results show the improved performance of the intelligibility of the autistic children while playing the computer game. Along with the traditional methods of speech development, we suggest these computer game as an attractive yet effective means of improving intelligibility in the speech of the autistic children.

Chapter 5

Improving the Fluency of The Speech

In this chapter, we introduce the basic of our second e-Learning game, the core components of the game, and our implementation procedure with software and hardware requirements for the problem of *"Difficulties in Making Correct Sentences with words".*

5.1 Introducing Our Gaming Software

We developed an interactive game where an autistic child who has already a rich set of vocabulary but is unable to complete a whole sentence has try to pronounce the names of the objects shown in computer screen within a short period of time. The core idea of the game is to simulate a sentence with a help of different object at the same time in computer screen as shown in the Figure 5.1. However, the process of object selection in this simulation is controlled by a human instructor from a remote computer. For example, if we want to simulate the sentence, "I eat ice-cream", then human instructor has to select the images of "A man"(it can be the image of the participant) ," ice-cream" and finally "A man eating ice-cream" from our image database sequentially. After the process of selection, the images are sent to the autistic child's computer through Local Area Network (LAN) and displayed in the Graphical User Interface (GUI). If he or she can pronounce the sentence correctly and completely, will receive virtual award (i.e. animated cartoon or any fancy thing they love).

(a)User Interface for the intstructor (b) A GUI with two objects at the autistic chid's end (c) A GUI with three objects

Figure 5.1: Three sample screen shots of our game

In Figure 5.1, we illustrate a simple example of this game. For example, after the initial set up, a user interface will appear at the instructor part as shown in Figure 5.1(a). Then the instructor will decide which sentence to simulate and select images accordingly from the database. However, there are many predefined simulated sentence in our database, so he or she can select directly that simulated sentence considering the level of ability of the autistic child. Then these images will be sent to the autistic child's computer and will be appeared in the screen as shown in the Figure 5.1(b). Besides, there is a counter to count how many words of the simulated sentence the player has been able to pronounce within certain time limit which ultimately helps the instructor to decide whether an autistic child is performing better or worse. Depending upon his or her success of pronouncing the whole sentence correctly the score will be saved in our database along with the corresponding difficulty level for future reference. Besides, results will be also shown in the computer screen of the instructor's computer, so that he or she can decide which simulated sentence should be generated next for developing his or her (autistic child) fluency in speaking. There is also a provision in our game where the uttered sentence is directly caught by the Speech Engine, converts to text and passed to the instructor if he or she (instructor) does not control the procedure manually.

5.2 The Core Components of the Game

The main portion of the gaming software consists of the following parts: (1) Java Socket technology for connecting two computer. (2) Swing Component of Java for the design of front end. (3) MySQL Database for storing images and score. Two interesting features of our newly developed game are (a) Completely platform independent (i.e. compatible in all kind of operating system provided the compatible JDK is available), (b) Very easily extensible image database with click and update option etc.

5.3 Our Implemented Approach and Result

During our 5 months of intervention, we had used our gaming software in an incrementing manner of the difficulty level of the sentence (i.e. 2 words sentence or 3 words sentence etc) to improve the fluency level of the participant. We not only increased the difficulty levels of the sentence but also set some certain time limits to pronounce the sentence correctly and completely.

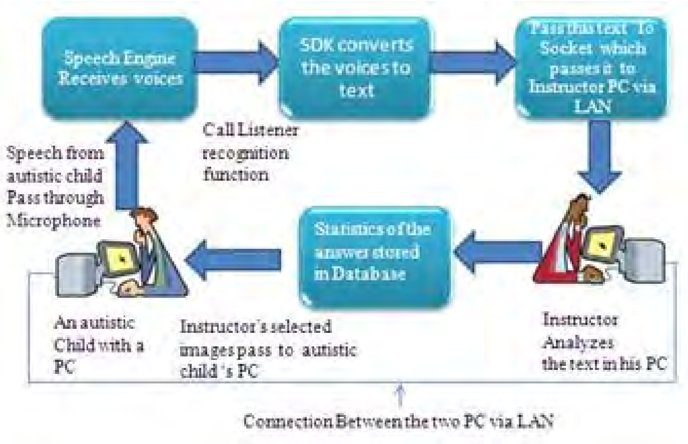

Figure 5.2: An overview of the experimental setup.

5.4 Experimental Setup

The basic setup of this experiment was rather trivial. The participant sits before the PC as she sued to be. The participant's PC is connected to the judge PC with a network cable. Hence, both of the computers have been connected over a LAN. The judge sits before the other PC and both of the PCs share the same screen. Whatever the participant does in the screen is being monitored by the judge. The judge also listen to what the participant says. Based ont hese two the judge gets the option to decide whether her responsed are correct or not. In Figure 5.2, we have illustrated the experimental setup that was used for improving the fluency in the speech of the autistic children.

5.5 How to Play the Game

First the instructor chose a set of images that could form a sentence and pass those to the participant's computer through LAN. The images would appear at the left of the screen and move toward the right until those finally vanished. We introduced this feature considering the fact that, this would give the autistic child more exciting gaming environment which in turn helps them to pronounce the complete sentence more quickly. We also introduced different difficulty levels determined by the number of words used in a sentence.

5.6 Experiments and Observed Results

Although the main target was to develop the fluency in the speech of the participants, we had to teach her some words first to enrich her vocabulary. We taught her new words using both traditional the picture exchange communication system PECS [13] method and our gaming software. In figure 5.3, we have illustrated the result obtained during these two processes. In the figure 5.3, we see that the points in the curve for Manual

Picture Method is always either above or on the every point of the curve of our proposed method which eventually indicates the supremacy of our gaming method for learning worlds quickly and efficiently.

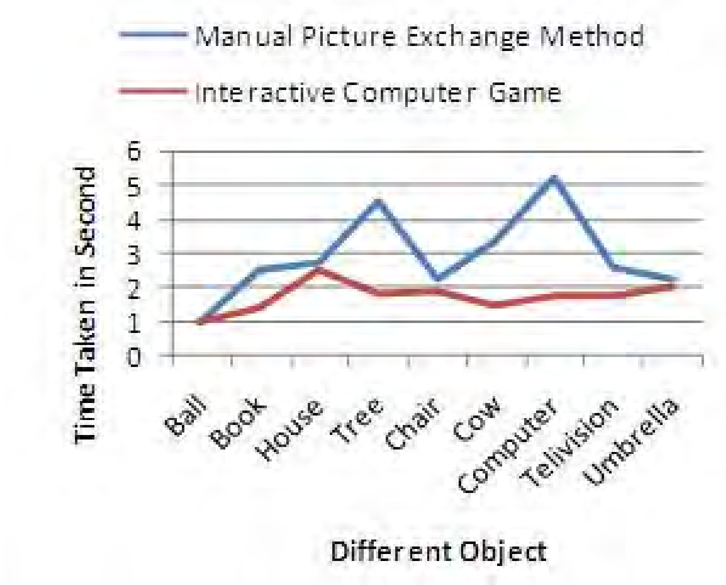

Figure 5.3: Comparison between two learning methods

Now, for developing fluency, our approach consisted of the following strategies.

- Initially a single word appears in the screen.
- Then a simulated sentence consists of two words.
- Then a simulated sentence consists of three words.

Besides, we maintained also data regarding the time taken by the autistic child to pronounce the words along with data of number of words they could pronounce in a single sentence. In 5.4, we illustrate a fraction of our data collected during our experiment. If we go from left to right in any row, we will notice that the time limit for pronouncing the word of the sentence is reducing. And if go from top to bottom in any column, we will observe that the difficulty level of the sentence is increasing. So, the leftmost top cell is

Time Limit → Object	10 seconds	7 seconds	5 seconds
Ball	✓	✓	✓
Book	✓	✓	✓
Tree	✓	✓	✓
Computer +TV	Computer(X) Television(✓)	Computer(X) Television(✓)	Computer(X) Television(✓)
Umbrella + Bicycle	Umbrella(✓) Bicycle(✓)	Umbrella(✓) Bicycle(✓)	Umbrella(✓) Bicycle(✓)
Cat + Dog + Lion	Cat(✓) Dog(✓) Lion(✓)	Cat(✓) Dog(✓) Lion(✓)	Cat(✓) Dog(✓) Lion(X)
Mango+Banana+Apple	Mango(✓) Banana(✓) Apple(✓)	Mango(✓) Banana(✓) Apple(X)	Mango(✓) Banana(X) Apple(✓)

Figure 5.4: Time taken by autistic children at different levels of difficulty of the sentence

the easiest and the rightmost bottom cell is the hardest. In any cell the ✓mark represents that the autistic child was able to pronounce the word of the corresponding row within given period of time. Similarly, the "X" mark indicates that the autistic child was unable to pronounce the word of the corresponding row within the given time. Besides, there were provisions for generating different kinds of reports (i.e. individual performance analysis in terms of difficulty levels, per week, month, etc.). These reports could be generated by our gaming software to help the instructor to analyze the performances easily.

5.7 Discussion

The results shown here clearly project the improved performance of fluency in the speech of the autistic children while playing our game. Along with the traditional method we suggest this game to be an effective means of improving fluency in the speech of the autistic children.

Chapter 6

Improving The Sense of Turn taking

Many people diagnosed with autism have difficulty with turn taking in reciprocal conversations and activities. This limits their ability to engage in social interactions since turn taking is the fundamental organizations of conversation and other types of communications. Conversations take place when interlocutors take turns responding to each other's queries or statements. Simply defined, turn-taking requires individuals to alternate between the roles of listener and speaker during the course of a conversation. The turn-taking system consists of two components: the turn constructional component and the turn allocation component. We use turns when we play football, talk to our friends, listen to our teachers or cross examine the defendant in the court. However, people diagnosed with autism do not seem exhibit those conversational attributes. Autistic children are less likely to make requests or share experiences, and are more likely to simply repeat others' words (echolalia)].

Effective turn-taking in conversations consists of three basic components: grabbing the floor, yielding the floor and keep the floor. Empirical studies demonstrate that people diagnosed with autism struggle understanding the cues that indicate the end of turns, or to interrupt, talking for too long, etc. Their inability to understand and exhibit those necessary components of conversations makes it difficult for them to make friends, resulting in social isolation. In this chapter, we introduce an exploratory speech and behavior interventions where we engage our participants in customized interactive games to help improve their sense of turn-taking (both one-to-one and multi-participant sessions). The games were designed be rapidly customizable, fun, competitive and rewarding to address the short attention span of individuals with autism. As these games are readily customizable to suit one's particular needs, condition, cultural familiarity, inclination etc., they are believed to be more effective than the traditional approaches of using flash cards.

6.1 Introduction to Our Game

6.1.1 Game development

To make the games readily customizable to meet individual's need, deficits and tendency, we used Scratch as the game development platform. Scratch is a drag and drop development tool and very easy to learn and use. In Figure 6.1, it can be seen that how easily the game is converted from one skin (Wall-E) to another skin (race between two participants). Any parent familiar with computer environment can be ready to program in Scratch in a week. Parents can change the code and the characters or the gaming environment very easily and they can use their photos, pictures of participant's familiar environment or the participant's face (Figure 6.4(a) and 6.4(b)) to make the game more real. They can also use sound clips of their own voice for the games.

6.1.2 Participants

This study was conducted at the Autism Welfare Foundation, Dhaka, a non-profit school that provides evaluative, therapeutic, and educational programs for individuals diagnosed with autism spectrum disorder. Eight participants with diagnosis of Autism Spectrum Disorder were recruited. Four of them had difficulties in speech and the remaining four participants were had clear and coherent speech. The last four participants assisted the first four participants as there conversation and game partners. The first four participants' age, gender, diagnosis, and objectives for speech-language therapy as listed in their school profile are shown in Table 6.1.

Table 6.1: Demographic information listed in their school

No.	**Name**	**Age**	**Sex**	**Diagnosis**	**Current Condition**
1	Siam	10	M	Mild ASD, Global speech	Echo, unclear words, repetitive behavior
2	Abir	11	M	Mild ASD	Full or partial unclear words
3	Tamim	7	M	Mild ASD	Some skill in making sentences
4	Omlan	8	M	Mild ASD, Global speech	Echo, repetitive behavior

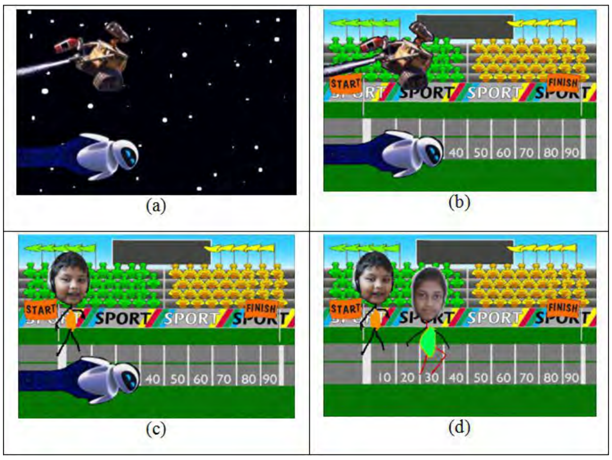

Figure 6.1: A series of screen shots showing how *Scratch* can be used to modify game

6.1.3 Eeperimental Setup

Our experimental setup has evolved over time through a few weeks of pilot studies with teachers, staff, and occasionally with participants. Before the experimental interventions, the participant was shown a large number of pictures of different objects and activities in monitor. The objects were selected based on social and cultural familiarity. For example, objects rife in Bangladesh such as mango, rickshaw, three-wheeler, etc. were chosen rather than pear or eighteen-wheeler. It also contained pictures of activities that the participants were familiar with, such as somebody drinking water, someone playing a harmonium, etc. The participant was asked to name the objects. The objects that he/she could successfully identify and label were selected for the next step. Then partner(s) was selected and the partner was asked again to identify and name the objects previously selected by the participant. Only those objects that both the participant and the partner could name were selected for final experiment. Figure 6.22 shows a diagram of the experimental setup where three participants are sitting in front of monitor. Here, it is expected that the right most participant will name the horse as his/her face has gotten bigger pointing his/her turn.

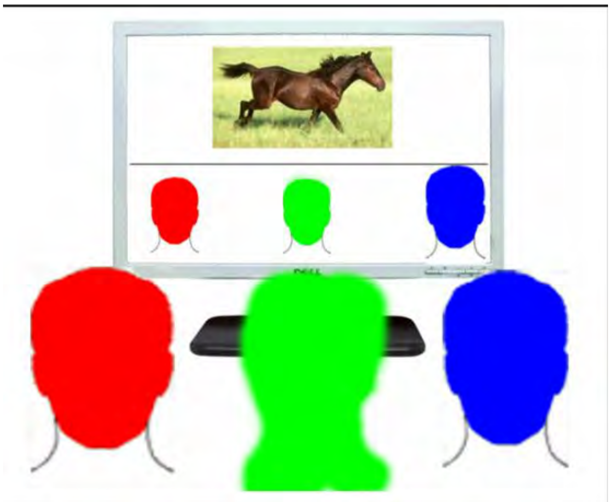

Figure 6.2: Tentative diagram of the experimental setup

The project was implemented on two phases each containing sequential and random turn-taking. To indicate turns, several incentives were applied. Some of the interventions were implemented using OLPC (Figure 6). In this way, the interventions can be carried out in cost-effective way. To hide computational effect, sometimes 'wizard of oz' method was applied (Figure 6.3(a)). The participants were oblivious of the fact that the experimenter was changing the pictures using wireless mouse and keyboard.

First Phase: Sequential turn taking

The first experiment was about taking turns sequentially. We take such turns during playing badminton, during debate, etc. The first phase was one-to-one turn taking. In the game, familiar objects would appear inside either of the two houses on the screen marked by participant's and partner's faces. To simulate real life experience, the participants were sitting in a way that there sitting position was similar to the position of houses; left house contained picture of the face of left participant and right house had face of right participant (Figure 6.3). Each participant was instructed to name only those objects that would appear inside the house marked with his/her own face.

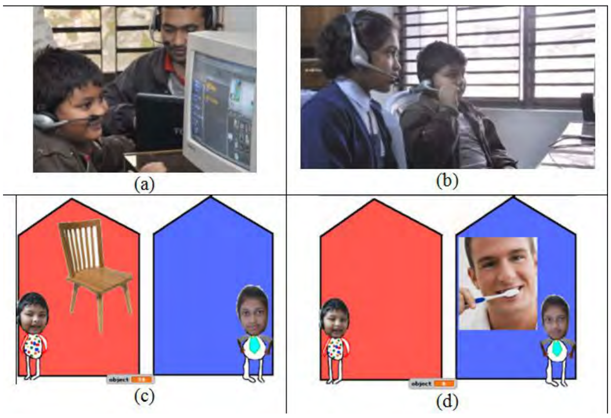

Figure 6.3: (a) Siam is selecting objects for turn-taking (b) Siam is playing games with his partner Pashla (c) Screen-shots of the game (Siam's turn) (d) Screen-shots of the game (Pashla's turn)

The participant's ability to name the objects at his turn and not responding at the partner's turn was noted. Also the time-span the participant could concentrate on the game was observed.

Second Phase: Sequential turn taking in random order

At the second experiment, pictures of objects would appear randomly inside either of the houses leaving no way to predict whose turn it would be. Sitting arrangement and position of faces on the screen was similar to that of sequential turn taking. The goal was to build the sense of taking turns in conditions where turns are not predetermined. We take random turns during conversation or playing badminton.

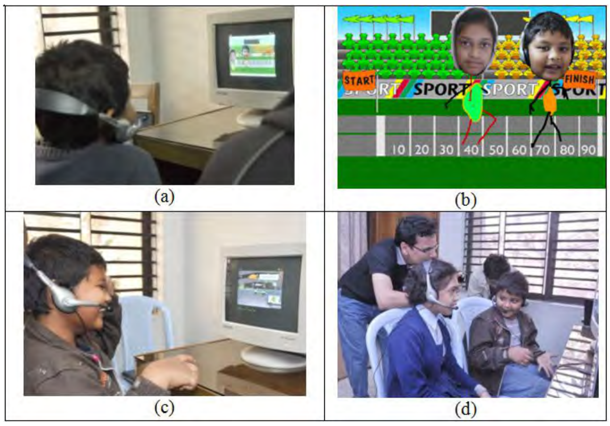

Figure 6.4: (a) Siam is playing games (b) Screen shot of the game (c) Siam is breaking in ecstasy having won the game (d) Siam is prompting his partner, Pashla, to respond at her turn

6.1.4 Third Phase: random turn taking

In the second phase, the goal was to teach the participant how to reciprocate for multiple cue situations. The gaming strategy was similar to that of one-to-one interventions. In this phase, the games had only one house and faces of three participants were shown bellow. The position of pictures of faces on the screen resembled the sitting arrangement of the participants as shown in Figure 6.5. To indicate turn, each time only one of the participant's faces would get larger and brighter. In this phase, sometimes one of the mentors participated with the children. 1) Sequential turn: At first the pictures of the objects were shown and turn was selected sequentially; every participant had his/her turn

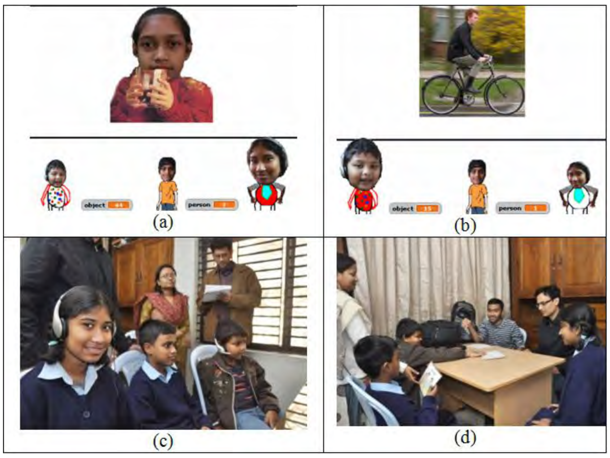

Figure 6.5: (a) Screen shot of multiple cue game (Mahira's turn) (b) Screen shot of multiple cue game (Siam's turn) (c) Siam with his two partners (d) Siam is applying his newly learned sense of turn-taking in real life scenario

one after another. The participant's response was noted duly. 2) Random turn: In the second experiment, the participants were shown the pictures and the turns were presented randomly.

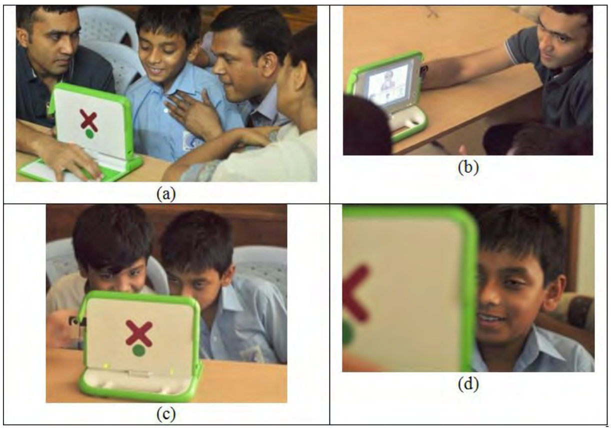

Figure 6.6: (a) Abir understands the game from the instructors (b) Turn-taking games in OLPC (c) Abir is competing to win a game with his partner (d) Abir is inspired enough to look at the screen though he has severe problem with eye-contact

After the interventions in computer, the participant would participate in real-life card-based turn taking session with there instructors and assistant's. It is shown in Figure

6.5(d).

6.2 Results and Discussions

Four participants and six partners participated in the program. Most of the participants showed significant improvement (some from 26.67% to 95.45% correct turns) in taking turns in any type of environment They also improved in paying attention longer than they would do in traditional methods. Not only they participated in the games with great joy but also they used to prompt the partners to name the object if the partners were a bit late to respond. This indicates improved capacity to mingle in social environment which is highly required to be successful in social and professional life.

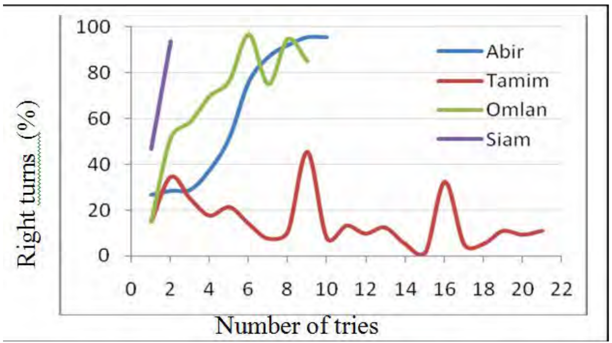

Figure 6.7: Participants' performance for one-to-one turn taking (percentage of time they took right turn)

One of the major problems involved in working with autistic children is that they do not tend to concentrate long to any intervention. This makes the improvement program very difficult to be effective. But our program proved to be very successful because these children tend to interact with computer more comfortably than with human participant. Figure 6.4 and 6.5 shows that his attention span increased with time while his attention break was reduced significantly.

To compete to win is an inborn tendency found in every child. In our intervention, we focused on exploiting the innate human nature to win or to gain the things they

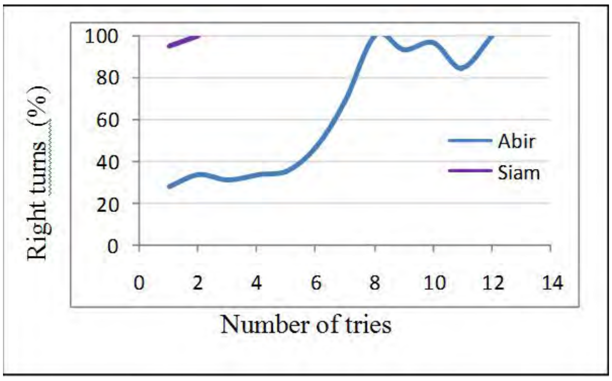

Figure 6.8: Participants' performance for multiple-cue turn taking (percentage of time they took right turn)

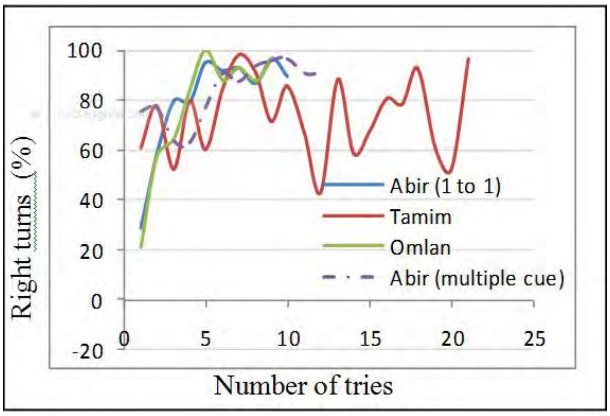

Figure 6.9: Participants' performance for multiple-cue turn taking (percentage of time they took right turn)

want in the virtual world of games to develop the skill of turn-taking in them. Although the initial results are very encouraging, there are still issues that we have to address in our future works. For example, the use of sounds and animations might help them in picking up the silent clues of turn-taking and in non-verbal communication; there are certain gestures which provide a social being with the necessary hints for taking turns. However, customizing the games we used in this intervention will help a lot of autistic children to get rid of their initial deficit in the sense of taking turns. From the quantitative analysis and the qualitative feedback from the guardians and the teachers, it seemed that our computer games could help the children in developing their sense of basic turns.

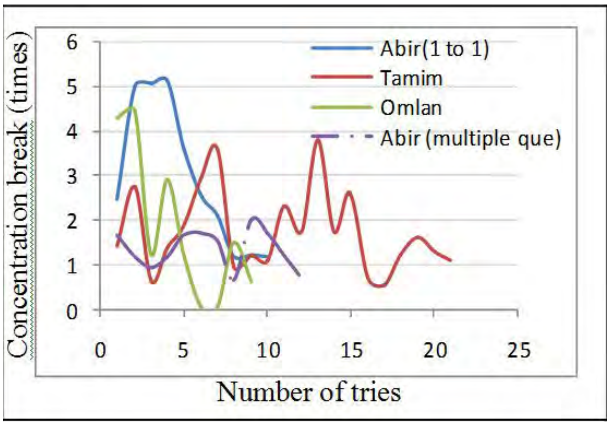

Figure 6.10: Participants' attention break (number of times participants lost there concentration per 10 minutes)

Besides the rapid development of the sense of when to respond in a conversation, our games could contribute to enhance the span of their attention in a training session. These results encourage us to extend this work by addressing other non-verbal social clues for turn-taking in a conversation. Our future works also include addressing of the turns in responses to questions and exclamations in spontaneous dyads or triads.

6.3 Speech Analysis

By turn taking, we mean the proper timing of starting and ending our speeches during a conversation. There are some invisible social clues which guide us to take proper turns. Autistic people miss these clues very often. We have worked on developing a computer game interface to help children build their sense of turn-taking. In this chapter, we try to detect turns in social conversation by analyzing the speech of the participants.

When we talk, we produce a speech signal. When we stop, the signal strength falls to (about) zero. But we stop:

- Between two words
- Between two sentences

- While changing the topic
- When we finish talking

Not all *stops* are turns. Only when we change the topic or finish the speech, a turn occurs.

6.4 Features of a Turn

Although we cannot define a turn completely, there are a few features of turns that we find from our everyday experiences and psychological literature reviews. Based on these features we try to address the corresponding effects on the speech signals produced by people during conversational discourses. Here we have briefly discussed those features from very general perpectives.

- **Silent Pause:** Every turn has to be a silent pause in one's speech. If someone doesnt make a pause, s/he is not actually intended to stop talking. So, it cannot be a turn. So, the first and most important condition of a turn is that is has to be a silent pause.
- **Undefined Length:** The length of the pause is not defined. It can be shorter, can be longer depending on the speaking style of different human beings. In our real life we actually incorporate facial expressions, gestures and many other things to a silent pause to get the clue that a person has actually left the floor.
- **Uncertainty:** It is not always necessary that another person will start speaking after a turn. The same person can take the floor again. So, it is not straight forward to determine when in a conversation we really get the opportunity to talk.

6.5 Detecting Turns by Zero Crossing Rate (ZCR)

When we continue speaking the speech signal continues to cross the zero level very rapidly. So, the rate of zero crossing is very high then. When we stop, the stop, ZCR decreases. Hence our primary assumption is: The ZCR is inversely proportional to the probability of a turn.

In the Figure 6.11, we see the sample taken from an audio speech and the the ZCR analysis on that. Later, we take the moving average of ZCR for smoothing the curve.

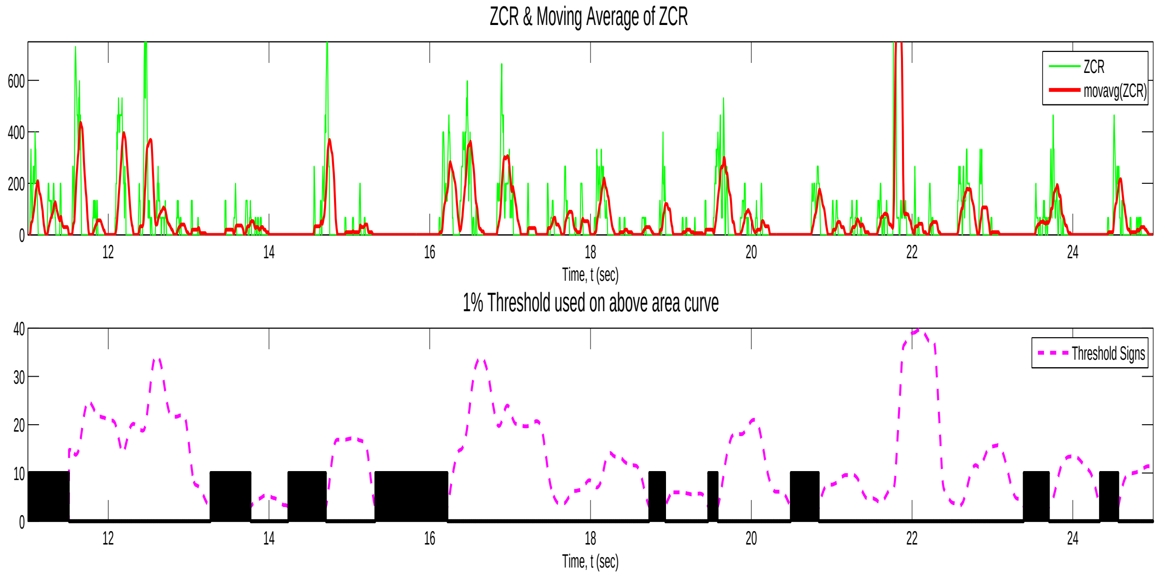

Figure 6.11: ZCR and moving average of ZCR

6.5.1 Time Framing

We divide the total time into a fixed number of time frames. Each of these time frames is called a time window. For each of this window, we take a single value of ZCR. This value denotes the number of times the signal crossed the ZERO line. The actual ZCR curve can be very spiky. Hence for a better result, we take the moving average.

6.5.2 Experimental Results for Zero Crossing

We ran an extensive test to get the performance of Zero Crossing hypothesis to get the turns in a running conversation. To evaluate the performances, we picked some conversation from the TOEFL and IELTS audio library. At first we counted the turns manually and recorded the number of turns against each of the recordings. then we ran our program and tried to determine the turn by speech analysis with ZCR. Table 6.2 shows the performance of turn taking using ZCR. Clearly we can see that ZCR detects more turns than the actual tumber of turns in the speech.

Table 6.2: Experimental results of detecting turn taking using ZCR

Duration	**Actual Turns**	**Detected Turns**	**Accuracy**
34s	7	15	37%
57s	13	18	71%
1:03 min	17	22	73%
1:20 min	14	21	71%
1:47 min	20	24	82%
2:00 min	19	21	89%

This table shows us the random performance of using Zero Crossing while detecting the turns. From this data it is hard to get if the hypothesis worked correctly. However, in maximum cases, it could detect the turns; but there were large number of false positives and missing turns present in the data. Hence, we understand that we need to improve the hypothesis to get a better result.

6.5.3 Problem with ZCR

ZCR sometimes fail to detect turn while people utter "Hmmm", "aaa" etc. In these cases, people offer turn, but as the sound value does not reach zero, the detector fails to determine that as a turn.

6.6 Detecting Turns Area Under the Curve

As ZCR solely cannot determine properly all the turns, we additionally check the Area Under the curve. The area implies the total energy delivered during a certain window of time. Hence even if we produce "aaaa", or "hmm", the area should have a larger vale that when we say nothing.

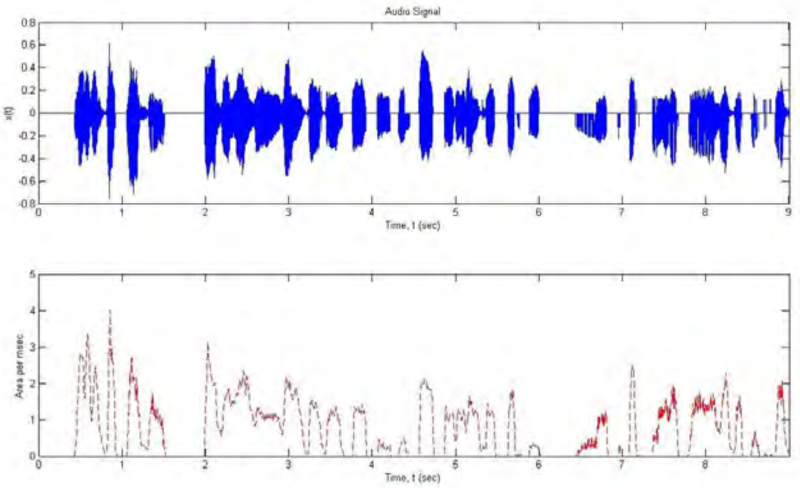

Figure 6.12: Detecting turns by Area Under the Curve

6.6.1 Experimental Results for Area Under Curve

For checking the performances of our assumption of getting the turns using the area under curve hypothesis, we set-up an experiment. Once again, we picked the audio conversation from the standard test libraries and checked the performances of our algorithm against the manually recorded data. We checked the performance of detecting turns by Area Under Curve upon 12 audio samples within 10 30 secs to 2 mins time span. The performances of detecting turns of 6 of them were as follows:

The following table, Table 6.3 shows the performance of turn detection with Area Under the Curve. Clearly this is better than ZCR but misses some turns which ZCR does not.

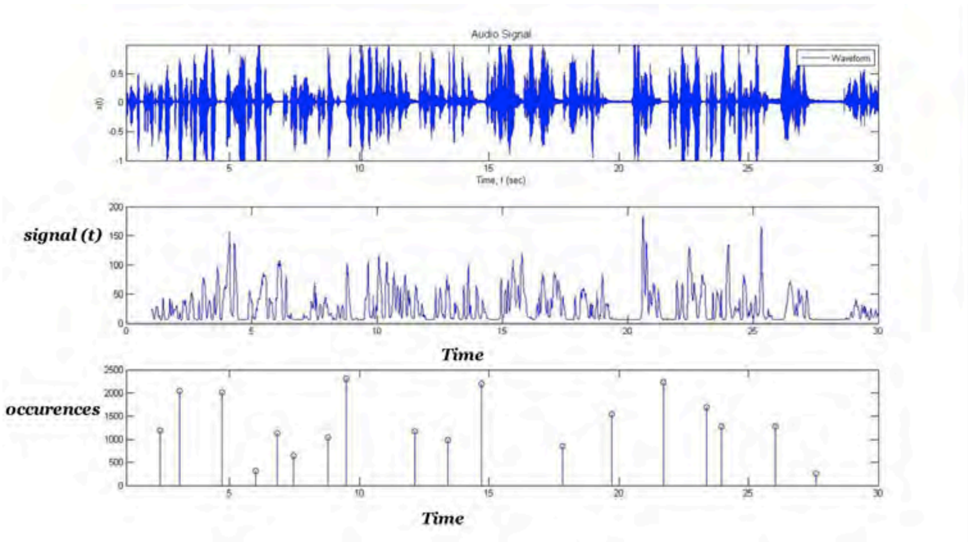

Figure 6.13: Detecting turns using *Area Under Curve*: Experimental result

This tablle shows us the performance of the speech analysis if we use Area Under Curve only. This led us to a better result though not near to perfection. A good number of turns were missing which had previously been detected by the Zero Crossing hypothesis. And there were some new false turns, too. Hence, it is clear that, this hypothesis alone is not also complete one.

6.7 Combining *ZCR* and *Area Under Curve*

Since both ZCR and Area Under Curve was not much successful in getting the turns in a running conversation, we decided to combine these two algorithms together to make a stronger hypothesis. In this algorithm, we first sort out the speech if those were turns just by ZCR with a certain value of threshold limit. If the rate goes over it, it certainly is not a turn. But, if the ZCR goes under that value, we were not sure if that was a turn. hence we make further test with Area Under Curve for that particular case. If that turns out to be a "Turn" by the area under curve hypothesis, too; then we decide in favor of a turn, otherwise not. For a better performance we now apply ZCR and area under curve together for detecting the turns in the speech. First we modify the speech with moving average as shown in the Figure 6.14.

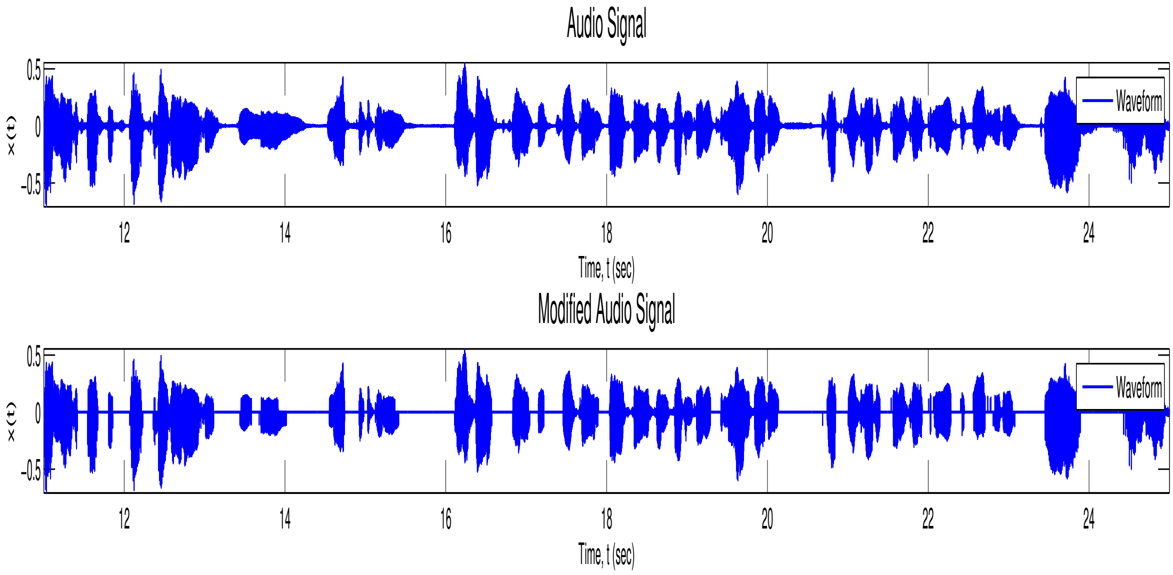

Figure 6.14: The original and the modified signal using moving average

Now we apply ZCR and Area Under Curve together and check the combined signal as shown in the Figure 6.15.

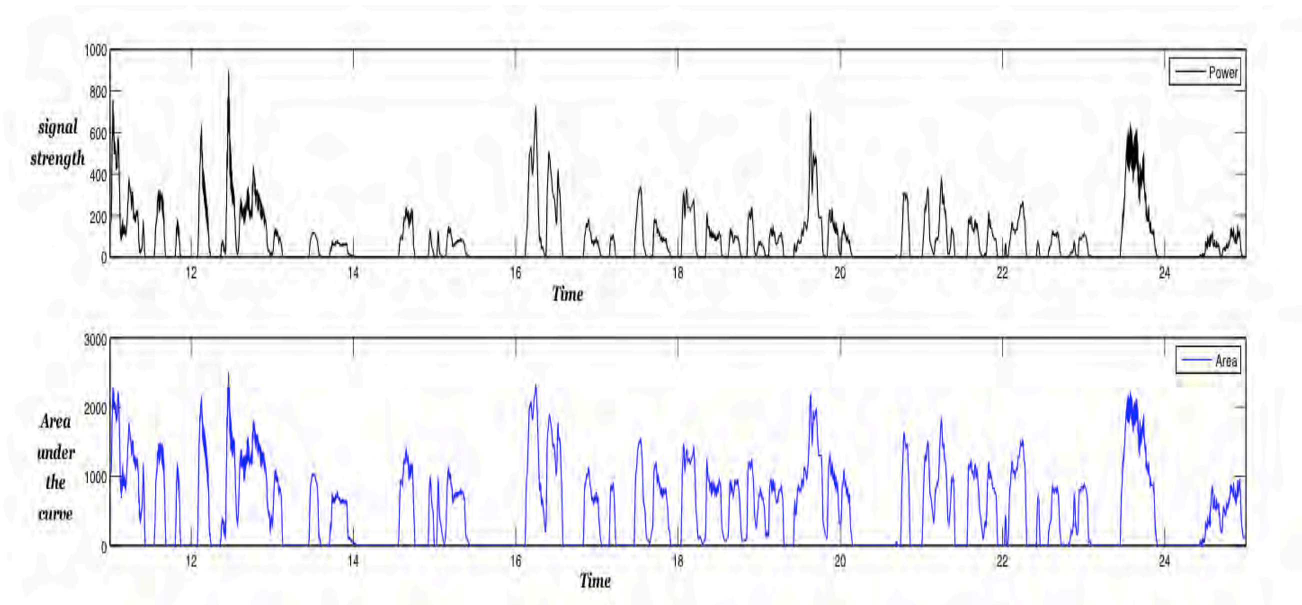

Figure 6.15: Applying *ZCR* and *Area Under Curve* together

Finally we detect the turns of the speech from this combined algorithm as shown in Figure 6.16.

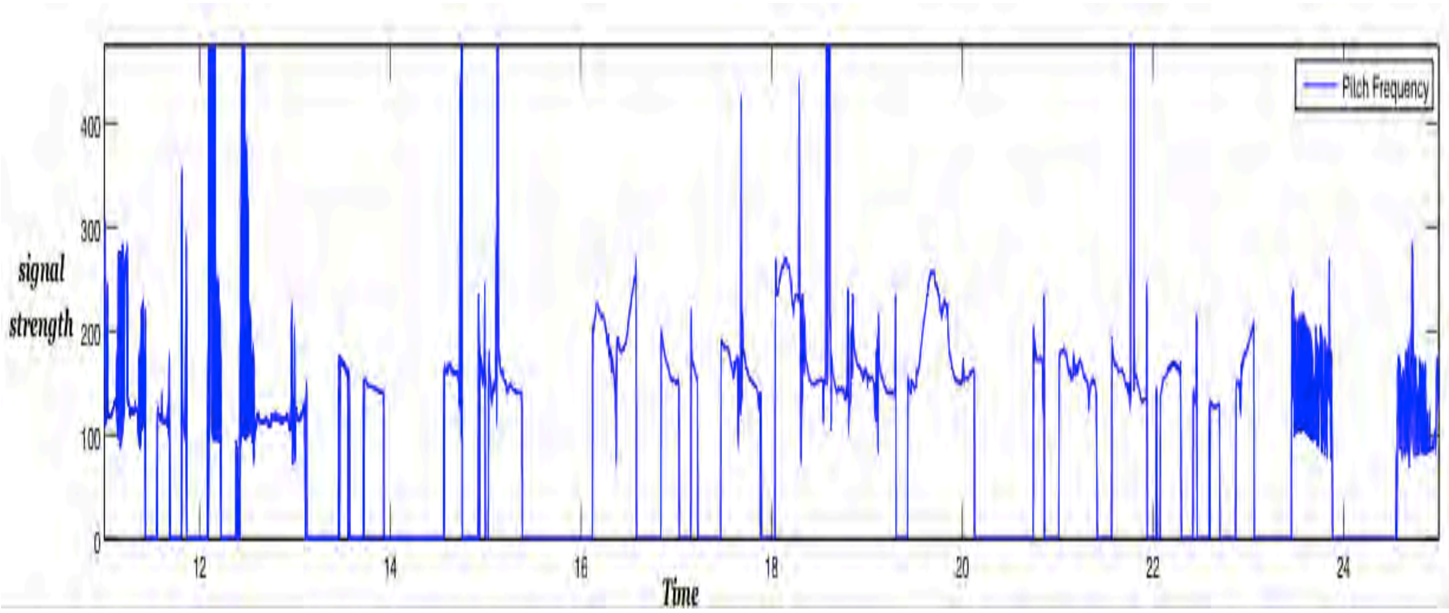

Figure 6.16: Turn detection with combined algorithm

6.7.1 Experimental Results with ZCR and Area Under Curve Together

For testing the performance of our combined algorithm, we again took the samples from the standard testing libraries. First we counted the number of turns in a conversation manually. then we ran the algorithm and checked how many turns it could detect correctly. Table 6.4 shown the performance of the combined approach of ZCR and Area Under Curve. Clearly this projects a better performance than the previous two.

This table a far better result that previous ones. The turn detection rate is higher here. At the same time, the false positive rate is also very low. This hypothesis almost always could detect the single turns and the turns in the conversation between two persons. However, it could miss some turns in group talks and there were some false positives in monologues. In any case, this hypothesis seemed to be much reliable that the previous

Table 6.3: Experimental results using *Area under curve*

Duration	**Actual Turns**	**Detected Turns**	**Accuracy**
34s	7	11	42%
57s	13	12	92%
1:03 min	17	14	82%
1:20 min	14	10	71%
1:47 min	20	15	75%
2:00 min	19	17	89%

Table 6.4: Experimental results of combined approach

Duration	**Actual Turns**	**Detected Turns**	**Accuracy**
34s	7	9	83%
57s	13	12	92%
1:03 min	17	16	91%
1:20 min	14	15	94%
1:47 min	20	18	87%
2:00 min	19	19	100%

ones.

6.8 Discussion

Our experiment on automatically detecting turns was not perfect; yet we could achieve a mentionable level of success while detecting turns in a running conversation. Actually, human conversation involves a number of social elements which can not be possible to detect by speech only. Although the prime media of a conversation is speech, we continuously pass a lot of social signals by our facial expressions and body gestures. With these, people of different culture have different ways of expressing their views in a conversation and the definition of turn is never fixed. For example, in many societies of Arabia and Africa, people do not mind talking while other person is talking. The competition for having the floor is explicit there. In some of these cases, it is not rare that the person with louder voice get the floor. But in western countries where people like to maintain a comparatively gentle pattern in their conversation are more likely to invite others to talk. In most of the cases, they do not start talking unless by requested by some other person. Hence, they do not look for the opportunity to talk and the sense of turns is totally different to them. However, in an average conversation, we tried to mix the features of a conversation and tried to figure out the occurrences of turns. With some erroneous result our system could perform well the sample sets. But we need to remember that, machine detected turns although might help an autistic child to react at the time of turns, it will never help him/her to understand when to react. So, this system will make them machine dependent. But the game we designed for them are targeted to build up the sense of turn taking in them; by which they will implicitly taught of how to take turns in a real life conversation.

Chapter 7

Conclusion

There is no definite solution for autism. Over the years, people tried hard to improve the socialization process of the autistic children using different therapies. With the advent of technologies, these therapies have changed their forms over the time. However, little success has been achieved so far.

In this research, we tried to address the major problems with the speeches of autistic children and tried to solve those with computer games. The main advantages of our games are that these are easy to implement, customizable and user friendly. The autistic children get attracted to these games very easily and hence, these were proved to be more fruitful to the young learners.

Our games were tried over the children of Autism Welfare Foundation (AWF) of Dhaka. With the limitation of the availability of the number of students and their variety we conducted our experiments and got some interesting findings. Those have been shown in this thesis. We would like to extend our works with a more reliable and dynamic e-learning platform in future. We will try to add the mobile devices as the platform to add the ubiquitous features to these. We are hopeful that the involvement of more people to this research would advance this in greater pace.

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