DESIGNING VIDEO GAMES AND INTERACTIVE APPLICATIONS TO ENHANCE LEARNING IN CHILDREN WITH AUTISM SPECTRUM DISORDERS

A Thesis

by

NAUREEN MAHMOOD

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Visualization

Designing Video Games and Interactive Applications to Enhance

Learning in Children with Autism Spectrum Disorders

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Approved by:

Chair of Committee,	Vinod Srinivasan
Committee Members,	Ann McNamara
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ABSTRACT

Designing Video Games and Interactive Applications to Enhance Learning in Children with Autism Spectrum Disorders. (December 2011)

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Autism Spectrum Disorders (ASD) are a group of developmental neuropsychiatric disorders that can be highly variable in their intensity and in the types of symptoms displayed among different people. Over the years, various intervention techniques using computer-based or computer-assisted therapy have been explored to help individuals with autism in their everyday lives. This paper proposes a set of special guidelines for developing computer-based interactive applications and games to assist learning in children on the autism spectrum. The guidelines proposed here form a framework of interactive and adaptive techniques to be employed in designing computer games and applications that can be used to enhance various aspects of learning and development in children on the autism spectrum.

These guidelines are based on the learning activities and other peer-to-peer interactions employed by teachers in inclusive classrooms which help optimize learning in a classroom environment. Other sources of game design considerations include prior research on the limitations encountered by children with ASD in motion, sensory perception, communication and cognition. Prior and ongoing research relating to their

abilities in these particular areas are also utilized in this study as important factors in designing the interactive applications and games. Lastly, studies regarding the use of technologies and augmented communication devices are used to help outline the necessary mediums of delivery for the games and applications.

The guidelines created in this study are introduced to parents and researchers of children on the autism spectrum through a survey in which these participants are asked to evaluate the techniques and technologies presented in this paper. This research delves into one of the new areas of exploration that have a huge potential in intervention techniques for children with ASD. It is expected that the outlines developed here will offer helpful insight into design and development for future efforts and advancements in gaming technologies for children with ASD.

DEDICATION

To my parents.

ACKNOWLEDGEMENTS

All praise for God, the most gracious and most merciful.

My sincerest thanks to my committee chair, Dr. Vinod Srinivasan, and the committee members, Dr. Ann McNamara and Dr. Ronald Zellner for their guidance, support and their continued patience throughout the course of this research. I would also like to thank Professor Philip Galanter for his special attention and help in several phases of this thesis.

I am also very grateful to my friends, colleagues, faculty and staff at the VIZ department for making my time at Texas A&M University a truly great experience. Lastly, I would like extend my gratitude to the International Institute of Education, who helped make my Master's studies possible through their gracious scholarship.

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1. INTRODUCTION

The purpose of this thesis is to draw up a framework of game-development strategies and guidelines for interactive systems and video games aimed towards helping to teach and increase interaction in children with autism spectrum disorders. The programs developed using the strategies presented here are not meant to replace a teacher, parent or guardian but they are rather meant as tools to further enhance the child's learning experience through the use of technology. This set of strategies and guidelines is for anyone who cares to develop an interactive program for a generalized or even a specific area of learning. The guidelines are based on the information from the experience of people with autism themselves, and the experience of their care-givers.

The guidelines presented here aim to repudiate the stereotypes associated with autism where people simply assume that the autistic child is incapable of learning or understanding complex concepts or that he or she is unable to process the information at the same rate as at which other children their age are being taught in a classroom. These earlier claims, as well as any teaching methods, games, or tools based on these claims only account for the disabilities or shortcomings experienced by the autistic child while not realizing the reasons behind the disability, which are, sensitivities to certain sensory stimuli. So, the strategies and guidelines to be developed here will be based on the understanding that the autistic child is not permanently limited in his or her learning but is in fact bothered by certain stimuli, or is prevented from learning and interacting with

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This thesis follows the style of *Development and Psychopathology.*

others properly due to the intensity of a certain sensitivity encountered by the child. So, the guidelines will in effect address the reasons that hinder the child's learning and will provide a framework for how best to create an interactive system that is built keeping these factors in mind.

In this section we go on to explain in detail what autism is, as defined by diagnostics, and the flaw in those definitions. Then we go on to discuss some key characteristics of autism. These characteristics will then form the basis for defining the guidelines for a functional and effective interactive system for children with autism.

1.1 WHAT IS AUTISM?

Autism Spectrum Disorders are a group of neural development disorders. They are referred to as a spectrum of disorders because the characteristics and symptoms can present in several different ways and can appear at several different levels of intensity for each individual. The essential features of Autism are described by the 'Diagnostic and statistical manual of mental disorders' (American Psychiatric Association, 1994) as "the presence of markedly impaired and abnormal development in social interaction and communication and a markedly restricted repertoire of activity and interests".

American Psychological Association further describes the possibility of a short period of normal development in which parents might even report the child as having learned a few words or phrases however, this period does not last longer than the age of 3 years. A child starts to display "delays or abnormal functioning" in at least one or all of the following areas prior to age 3:

- Social interaction
- Language
- Symbolic or imaginative play

It is a want in these particular areas of learning that produces the subsequent social , cognitive and learning limitations in a child with Autism Spectrum Disorders.

However, these definitions only look at the 'outward' image of autism without much insight into what the autistic person feels about the effects of their disorder and about their own limitations. In fact this model of viewing ASD may also assume that all individuals on the spectrum would also lack any understanding of their own disabilities, which is largely untrue (Kluth & Olcott, 2008). One can not know how to better understand the difficulties that hinder the learning process of an autistic person without understanding how the disorder really makes each individual feel, how it differs from person to person, and what might be similar among the people with various degrees of intensity of the disorder.

Furthermore, outsider definitions of autism only focus on the deficits and flaws in a person's abilities and do not take into account a person's strengths and the abilities that they do excel at. For instance, the methods of diagnosis appear to use words and phrases that show the autistic individual to be fixated on certain objects or to be unable to perform a particular task. This is incomplete information when the observer himself is unable to report or understand the cause of the fixation or inability. The cause could be anything from being sensitive towards a certain sight, sound, smell, light, motion or a

touch. Focusing on such stimuli is the key towards understanding what people may define to be 'autistic behavior' of such an individual:

> No one has taken the time or effort to include anything from the actual experience of the autistics. I assume this is because we do not believe that they are capable of sharing anything useful. However, if the direct experience of those who are diagnosed with depression or social phobia is considered valuable information, why are we not accessing the same from those who have autism? I expect that this lack of input from direct experience invalidated the whole process of diagnoses.
>
> (Gillingham, 2000)

1.2 COMMON CHARACTERISTICS

Although no two people with autism encounter the same difficulties or sensitivities, or "behave, communicate or learn in the same way", some of the main characteristics, as described by Paula Kluth in her book *You're Going to Love this Kid!*, (Kluth, 2003), are:

- Movement differences (excessive atypical movement or loss of typical movement)
- Sensory differences (vulnerability to sensory overload, making the person feel confused, unfocused or tired. Can even cause pain)
- Communication differences (trouble using language or words, difficulty understanding and using conversational timing and rhythm)
- Socialization and interaction differences (lacking skills in successful "typical" social interaction)

- Learning differences (ambiguity in the way a task is assigned sometimes may lead the observer to mistakenly conclude that the autistic child is incapable of performing or understanding the task.)
- Perseverance on certain objects or topics (a deep interest and fascination with a particular thing such as a machinery or a locomotive).

1.3 PROBLEM STATEMENT

Autism is a neurological disorder which, as all neurological disorders go, is still quite a mystery to researchers (Willingham, 2008). The knowledge base for autism is constantly evolving and new treatment techniques are constantly being explored and incorporated into the existing intervention techniques. At the same time, several methods and intervention techniques are also being discarded over time for being obsolete or flawed. There are three main reasons for this constant change in our knowledge and understanding regarding autism. The first being that the understanding of all neurological disorders is still lacking in many ways just because there isn't complete knowledge of how the brain works (Pedersen, 2010). So the field of neurosciences itself has a long way to go before we can have much deeper understanding of the autism spectrum, among other things. Secondly, as mentioned in section 1.1, the way we evaluate the capabilities and limitations of individuals with autism is from an outsider's perspective. This problem is gradually being addressed as more and more people who have grown up with autism and have been able to overcome their communication difficulties to some extent are being encouraged to talk about their disabilities. More

intervention techniques encourage autistic children to explore learning in their own ways and try to help them learn how to become responsible members of society through more awareness. But, it's still not nearly enough to counter the predominant methods of evaluation if the patients' narratives are not taken into account in the case of a neurological disorder. This creates the possibility of encountering certain pitfalls such as the assumption that the child has retarded learning and is therefore incapable of understanding certain concepts altogether. Lastly, the most important problem being with the wide spectrum of disorders that autism encompasses, as discussed in section 1.1. The symptoms and intensity of autism differ greatly from one person to another.

These problems are currently faced by most interactive systems or computer games being used to engage children on the autism spectrum. In some cases, the interaction capabilities are limited by the input method the child can use (Farr, Yuill & Raffle 2010; Khandaker, 2009), while in other cases, games are not designed to offer enough in the way of learning beyond a very basic skill or two (Chen, n.d.). Others that are good at providing stimulation and learning in the same environment do not provide the controls, visuals and/or game play options with enough flexibility for individuals with severe symptoms of autism.

Lastly, it is important that the potential of video games be taken beyond interaction through controllers (limiting the usefulness for individuals with severe sensitivities) and beyond on-screen interactions with only virtual characters. It is also important to introduce and encourage peer-to-peer interactions on screen and off. These two areas are yet unexplored in the realm of gaming for individuals on the autism

spectrum but offer a huge potential in boosting communication skills as well as inclusive learning through the use of gestures, expressions and speech recognition for a child with ASD.

1.4 SIGNIFICANCE

The need for interactive systems for people with autism emerges from the difficulty faced by the autistic community in carrying out social interactions in general. The significance of computer games and interactive applications stems from their ability to be engaging, evolving and personalized. The evolving nature of what we know about this neurological disorder can be very easily taken into account into a good game design. Such interactive applications also have the ability to be adaptive towards the communication, learning and sensory differences that are found among the individuals on the autism spectrum. Lastly, as mentioned in the previous section, the most recent developments in input techniques can provide a chance to interact through gestures and speech without needing physical controls.

Given the several factors that might hold the autistic child back in their learning, any tools to assist this process help a lot along the way. So, this research aims to formulate a set of necessary strategies and guidelines that can be the basis for building better tools that can be more effective in helping children with autism learn anything from basic interaction, identifying emotions and attitudes to complex language and mathematical structures.

1.5 MOTIVATION

A lot of existing teaching methods as well as tools meant for assisting student learning appear to end up not being useful enough when it comes to teaching children with learning disabilities. This is because of the constraints and limitations built into the design. Be it classroom games and activities, computer-based activities, interactive toys or even educational electronics, all interactive systems are built with a certain mind-frame and a certain understanding of a logical unfolding of events. When presented to children with a learning disability and especially those with autism, these games or interactive systems might not make sense right away. The child might even severely dislike the game, the reasons for which could range from a certain sound, a certain color or a certain object in the game, to the even the sounds of the fans in the computer itself or the place where the computer is placed. But, in cases where a child with autism is either non-verbal or is otherwise unable to express his/her unease with the program, the child would simply resort to shouting or screaming to get away (Koppenhaver & Erickson, 2003). In such a situation, most people would simply assume this behavior to mean mental retardation or that the child is unable to understand the requirements of the interactive system.

This is a common mistake among several people (teachers, guardians etc) who are faced with a child on the autism spectrum. It leads to several of the children with autism never being given the challenges, or the proper educational attention that they require. They are instead simply assumed to be not intelligent enough to be able to grasp the more complex concepts of learning taught in a class.

However, from the experiences of many autistics and long-time teachers of autistic children, it has become quite clear that the behavior as well as the learning problems of such a child can be overcome with just a little bit of experimentation. Simply playing around with different strategies, trying to use basic communication methods, and not giving up on the child just because one single method doesn't work; these would be a few simple strategies to start with. Learning from the experiences of such people, this thesis aims to translate their findings into creating a framework for interactive systems that can be used by the child in conjunction with everyday tasks, just as a form of educational entertainment. The necessity of this thesis is due to the lack of the above understanding in people who are invested in creating games and educational material for autistic children. So, this thesis aims to create the guidelines for basics in game design which people in this field can use to base their educational games and other interactive systems on.

2. PREVIOUS / RELATED WORK

Real life interaction-based techniques are most important for children with autism because they aim to introduce, familiarize and help the child cope with real-life environments, social interactions and imaginative play when the child is unable to learn these on their own (Kluth & Olcott, 2008). Several of these techniques have been tested time and again in real life situations by care-givers, researchers and teachers of autistic children over the span of decades, and they have also proven their worth. Even with the vast differences among people on the autism spectrum, with good supervision the person-to-person programs have the flexibility that they can be customized towards the needs of the child. This way, the care-givers and teachers of the child can experiment and learn within the program to see what methods and strategies work best for their child.

The most important aspect of real-life programs is the use of inclusive environments, such as inclusive classrooms and play-time activities involving other kids. A child with autism may not be perfectly willing or capable of understanding and taking part in the inclusive environment as easily as other kids might. However, separating them from normal activities and/or excluding them from the general classrooms and limiting them to 'special learning' areas only makes it harder for them to ever be able to accept and understand aspects of social interaction and game-play as they grow up. Teachers might find it easier to simply put the autistic child in a separate 'special learning' class but, this general practice is based on the assumption that the autistic child

is altogether unable to learn at the same pace as the other kids in the classroom. Instead, the solution should be exploring and trying alternative teaching methods which might then go on to prove the autistic child is capable of learning better by simply addressing some of his or her sensory issues, e.g. having the child sit away from the windows, if he/she is especially sensitive to the bright sunlight or to sounds from a nearby highway (Kluth, 2003).

The possible benefits of using computer-programs to indulge and engage people with autism spectrum disorders for educational or interactive purposes have started receiving wide recognition in recent years. These potential benefits have already been the target of much recent research (Leonard, Mitchel & Parsons, 2004; Farr & Jacklin, 2005; Khandaker, 2009). The virtual scenarios created in computer-based applications can offer a monitored and predictable environment where the visual and auditory cues can be planned to be aimed towards individual needs of the users (Swettenham, 1996). Visual and auditory content and input can be planned and controlled directly, allowing the player to focus only on the in-game tasks without distraction or confusion from extraneous cues as experienced in social interactions (Wilson, Foreman & Stanton, 1998). The content of a computer application can be designed to present necessary tasks or teach required skills consistently and repeatedly, without the boredom and fatigue that can sometimes occur with task repetition by human instructors (Brown, Standen & Cromby, 1996). For instance, interactive multimedia computer programs have been effective in teaching vocabulary (Gilberg, Nelson, Tjuis & Heimann, 1995) as well as improving motivation and attention during learning (Bernard-Opitz & Chen, 1993). The

game content can also be aimed at enhancing and refining peer-to-peer interaction as well as at teaching about emotions (Silver & Oakes, 2001) and social problem solving (Bernard-Opitz, Sriram & Nakhoda-sapuan, 2001).

The usefulness of virtual environments has also been put to test through fully immersive systems, such as those with a virtual environment, headsets and gesture tracking systems (Strickland, Marcus, Mesibov & Hogan, 1996). However there are several problems when dealing with a fully immersive environment which became apparent immediately, such as instructing a child who might be non-verbal and / or have a speaking vocabulary of only a few words on how to use the technology. Other problems include the child's uneasiness in using head-mounted displays, confusion in adjusting to the interface and visual overlay created in the virtual world by moving in the physical world. Limiting factors also included the after-effects of "cyber-sickness" (headaches, feelings of nausea, dizziness).

Alternatively, using a desktop or portable computer the child with autism spectrum disorder can be given the tools and symbols to support and enrich social interaction (Farr & Jacklin, 2005). Unlike the unpredictability of real-life social interactions and environments faced by people with ASD, where being unable to understand different peoples' responses might not only be a cause for added stress for a child with autism but, may also be hugely varied across different people, computers have a predictable response based simply on the inputs from the user and not on its underlying emotions. Moreover a computer would not react to atypical behavior of a child with ASD such as rocking, screaming etc. as a human would (Jordan & Powell, 1995).

Several technologies designed to facilitate learning about emotions and social interaction for children with autism by using predictability and 'common interests', such as such as trains, LEGO, fire-trucks etc. are also currently being widely researched. One such example is the Transporters CD-ROM (Chapman, Golan, Baron-Cohen & Granade, 2007) which uses colorful animated trains and cable cars with highly expressive human faces superimposed on them to teach the children how to read and identify emotions. Furthermore, a branch of intervention techniques known as 'affective computing' attempts to put the predictability of computers to use through wearable technology which provides feedback about the wearer such as heart rates and galvanic skin responses. These responses can then be utilized in the design of the virtual /real-world interactions in a way that support and enhance learning on individual basis.

There are also a few recent developments in computer and internet based games that are worth mentioning here. One such example is the set of simple click-and-play games created by Eric Chen (Chen, n.d.). The games aim to teach how to identify simple facial expressions and everyday objects through sparse screens with a very simple mouse-clickable interface. These are some of the very first games to appear on the internet that were aimed specifically for children with ASD, so the material and interface design provides little information or learning beyond a very basic set of skills. Another set of internet-based games are the ones created by Whiz Kids Games (Whiz Kids Games, n.d.). These offer much more in the way of variety and levels of learning. Even though each individual game focused on enhancing one or two specific skills (such as path-following, hand-eye coordination, recognizing facial expressions), they also offer

the player a chance to promote to higher levels of skills at their own pace. Each game also makes use of cut-scenes during game-play which introduce the characters and provide information about the upcoming tasks. Yet another computer-based game is the EASe Funhouse Treasure Hunt (EASe: Electronic Auditory Stimulation effect, n.d.) which provides a 3D environment where the player has to navigate through a children's play-room while riding on a truck. The game addresses some specific areas of interest related to children with ASD, such as a common interest in vehicles like trucks and learning to navigate and identify different objects, while it might seem to have adverse effects in some areas related to visual stress, movement and tracking problems as well as the effects of cyber-sickness mentioned before.

These developments in the use of computer-based games in the recent years has been encouraging however none of the examples mentioned above have been put through any clinical experiments or have been analyzed by experts for their effectiveness and the methods used for designing the games. So even though these games may possess certain strengths in specific areas of learning however, there have been no studies to address the effectiveness of these games with children on the autism spectrum.

3. METHODOLOGY

3.1 DETERMINING GAME DESIGN CONSIDERATIONS USING A 'SOCIAL MODEL'

For an outline of game design elements, this research delves into a 'Social Model' of autism as described by Paula Kluth and Kelly Olcott in their book titled 'A land we can share: Teaching students with autism in an inclusive classroom' (Kluth & Olcott, 2008). This view provides an insider's view of autism and an elaborate illustration of some significant considerations for an environment that promotes successful learning and development for individuals on the autism spectrum. Even though this social model is the basis for game design considerations in this study, it is as yet a non-exhaustive model of autism due to the ever evolving nature of the intervention methods and the wide spectrum of disorders contained within ASD.

To explore this social model, the following aspects of successful learning environments will be used to flesh out the game design requirements and considerations from:

- Understanding differences and their effects on literacy and behavior
- Movement differences
- Sensory differences
- Communication differences / social differences
- Adapting to the differences

- Identifying common interests; investigating simple ways to incorporate these into educational games.

As far as game design strategies are concerned the aspects of successful learning described above will be important in identifying important factors to be taken into account when choosing game genre, storyline, environment, content, user-interface, game-play and game mechanics.

Some other aspects of inclusive classrooms that need to be taken into consideration for interactive game-play are: maintaining high learning expectations from children with ASD, providing models of social and literate behavior through in-game strategies, and adopting "elastic" instructional approaches. These considerations are important to create a much needed appeal for the games while also providing the necessary awareness for literate and social behaviors.

3.2 SURVEY OF GAMING TECHNOLOGIES

After creating the guidelines for game design a survey was also carried out to evaluate the usability of existing gaming technologies and to receive feedback about the methods suggested in this thesis for integrating these technologies with the game design guidelines. The participants of this survey included parents, care-givers and researchers currently working with children who are on the autism spectrum. Before presenting the guidelines in this paper and making them available for further implementation, it was important to test the validity of the game design considerations proposed in this study. Therefore, the evaluation of this thesis was carried out through the survey.

4. IMPLEMENTATION

The purpose behind choosing a social model of autism to interpret into game design guidelines, rather than the medical model, gives us the opportunity to recognize and take into account the social barriers encountered by the individuals on the autism spectrum that root not only from their own needs and differences but also from the attitudes and perspectives of those without the 'autistic' label. This makes sure that the guidelines are not limited by the barriers while also making sure they are not limiting the individuals to the barriers defined by outsiders' attitudes. To achieve this balance, the game design elements proposed below are examined with respect to the differences in movement, sensory perception, communication and learning experienced by autistic individuals.

4.1 UNDERSTANDING DIFFERENCES BASED ON THE SOCIAL MODEL

The differences in areas such as movement, communication and learning that are experienced at different levels of intensity by different people with ASD usually give an outsider the erroneous impression that the autistic person is not adept at learning basic skills, performing simple tasks or remembering minor steps for a certain action. While the truth is, there is a great effort required from those with ASD for undertaking a lot of tasks that might seem so easy to others. This great effort is due to the differences in movement or perception, and not a deficiency in cognition or learning ability. These characteristics play an important role in defining the guidelines presented here. The

structure and design of any game for use by individuals on the autism spectrum strongly depends on understanding them and implementing appropriate interaction and game-play mechanisms.

4.1.1 Sensory Differences

Sensory Overload: This is a very common effect of the heightened senses possessed by most individuals on the autism spectrum. This can be triggered simply by continued low-level bombardment or sudden changes in surroundings (Blackburn, Gottschewski, George & Niki, 2000). Therefore, several autistic individuals are vulnerable to such a sudden overload which may cause confusion to others, while causing both confusion and pain to the autistic individuals:

- Touch: It is not uncommon for several individuals with ASD to avoid being touched or to be able to tolerate only certain types of touch. This sensitivity extends to their reluctance of touching certain materials and textures.
- Hearing: Some individuals may be bothered by a range of sounds that may not even be detected by or sounds that may sound benign to the average person (Fihe, 2000).
- Sight: Visual sensitivities for persons with ASD can be triggered by certain kinds of light, color and patterns. These sensitivities can not only have profound negative effects on the person's sensory system but may also cause tremendous fear and anxiety.

- Heightened Senses: It is also important to note that the sensory differences that exist among individuals with ASD are not only the negative kinds. There are several cases where the heightened senses are a cause of great comfort and enjoyment. Several autobiographies of people on the autistic spectrum who have successfully overcome their difficulties report special strengths in visualization that they attribute to their autism. As Temple Grandin, one of the most articulate authors on this subject wrote:

> I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-color movies, complete with sound, which run like a VCR tape in my head. When somebody speaks to me, his words are instantly translated into pictures.... I value my ability to think visually, and I would never want to lose it.
>
> (Grandin, 2006)

Sensory differences are helpful in determining the elements of game content concerning visuals in the game environments and those involving characters. These are examined in sections 4.2. Elements that concern touch sensitivity are also discussed in section 4.4.

4.1.2 Communication Differences

- Difficulties in Speech: It is not ideal to limit the interaction to verbal commands, or expect a certain level of capability in speech. A number of children with ASD experience trouble using language, may use few or no spoken words or may be limited to repetition of a few words or phrases. They

are not and should not be considered limited in their learning or comprehension due to the limitations in their speech. (Stokes, 2001)

- Eye Contact: For most persons with autism, making eye-contact during a conversation can be very frustrating and uncomfortable, and not especially helpful as a communication tool (Kluth & Olcott, 2008).
- Pragmatics: How to enter or exit a conversation, adjusting to different partners in a conversation, reading general conversation cues, staying on the topic, switching topics and general turn taking are all some of the common concerns shared by individuals on the spectrum.

Considerations regarding communication differences are an important component in designing appropriate story lines and themes for games and interactive applications as examined in section 4.2.3. These differences are also important to consider when determining the user interface and input/output device preferences as described in section 4.3.

4.1.3 Movement Differences

- Involuntary Movements: Many people with autism experience significant movement problems on a regular basis. Behaviors such as hand flapping, rocking back and forth and jumping are mostly involuntary reactions to some discomfort they may be experiencing. In other cases behaviors like gaze avoidance and excessive pacing are even deliberate efforts by some to enhance attention (Donnellan & Leary, 1995).

- Hand-Eye Coordination and Motor Skills: For some with ASD there is an extraordinary effort and concentration required to suppress extraneous movements, channel their efforts towards a particular movement and maintain control of it. (Kluth & Olcott, 2008) These kinds of difficulties may become a hindrance in simple tasks such as drawing recognizable figures, writing and operating a computer efficiently.

An impaired perceptual ability in autism has been shown for some domains such as non-linear, high velocity motion (Spencer et al., 2000; Milne et al. 2002; Bertone, Mottron, Jelenic & Faubert, 2005). There is also a predominance among individuals with ASD to experience 'motion sickness' through visuals that demonstrate fast moving first person view.

These differences would have an impact on determining the elements concerning content within a game such as game environments, visualizations, animations and character movements, which are described in more detail in section 4.2.2 and 4.2.3. These differences also have a bearing on game mechanics as explained in section 4.2.4. Section 4.3 details the impact of these differences on user interface, input / output modes and devices.

4.1.4 Areas of Conflict / Diverse Views

There are certain areas of visual perception for individuals on the autism spectrum that have received contrasting reports. There are a few studies that show children with autism to be limited in their abilities related to these areas, while others

support the idea of children with ASD to have heightened abilities in these areas. Some of these areas of visual perception heavily influence game content and gameplay design as well. The details of how these may be used for game design considerations are discussed in the sections 4.2.2 and 4.2.4

4.1.4.1 Color Perception

Research involving limitations in identifying colors in different settings and on-screen environments have been conflicted. There are some studies to support the idea of superior color naming and color obsession in children with autism (Moore, 2004). Whereas some of the other more recent research points to children on the autism spectrum as having less accurate color memory, search and detection as shown by Franklin et al:

> Children with autism were significantly less accurate at identifying a colored target on the two tasks compared to controls. Importantly, this was found for all three color regions (red, green and yellow), suggesting that this pattern is not restricted to certain regions of the colors pace.
>
> (Franklin, Pilling & Davies, 2005)

This might be just an instance of the vast spectrum of the ASD presenting in different ways which may not be easy to classify. But, there is no consensus on this matter and both cases could have some bearing on the outcome and effectiveness of an interactive program that relies on colors and visuals.

4.1.4.2 Pattern Recognition

Individuals on the autism spectrum have been reported to show superior ability in finding embedded figures suggesting a special facility in seeing parts in wholes (Shah & Frith, 1993). The ability to learn and recall random strings of words as compared to meaningful prose has also been found to be more advanced in children with autism. (Hermelin & O'Connor, 2011). Similar abilities are found when using random or structured strings of words or color. They appear to process unconnected stimuli quite remarkably, opposite of normally developing children's performance (Shah & Frith, 1993).

Those with autism show superior visual discrimination (O'Riordan & Plaisted 2001) or an enhanced perceptual functioning that may extend to a large number of perceptual domains (Mottron, Peretz & Menard, 2000).

4.1.4.3 Spatial Abilities

Spatial abilities are reported to more advanced in certain people with autism. There have been reports of keen interest and superior ability in tasks involving maps (Caron, Mottron & Rainville, 2004) This is expected in relation to the strong pattern recognition skills and this is demonstrated through visuo-spatial tasks that involve recognizing and memorizing landmarks and in identifying similarities between map and landscape features.

4.1.5 Common Interests

Although the differences among people with autism abound, some general characteristics are shared among them as well. Therefore, for designing a successful learning program for people on the autism spectrum it can be very beneficial to utilize the commonly shared interests. For instance, trains and trucks are a very common special interest among people with autism. However, in most cases, the child with ASD is discouraged from pursuing these interests because of their tendencies to perseverate on these interests.

> Trains are a very common special interest among people with autism. If it's seen and treated as a "perseveration" (as an inhibiting obsession, not as an interest), it's easy to be worried about it... Special interests like trains... animals... video games... movies... action figures and more are all direct routes to your child's heart. And every one of those interests (and most others) can become a gateway to learning, friendships, careers and adventures. The key is to find and provide the opportunities to take the interest from perseveration to hobby - and, perhaps, from hobby to career.
>
> (Rudy, 2009)

Some of the other commonly shared interests found across individuals with autism include:

- Vehicles: trains, trucks, fire engines, buses
- Objects: light switches, musical instruments, electronics, computer games
- Animals: horses, cats, monkeys, lizards, dinosaurs(!)
- Subject areas: outer space, math, science, drawing, meteorology.

These special interests facilitate in determining the contents related to characters and themes of a video game. These influences are discussed in sections 4.2.2 and 4.2.3.

4.2 DEVELOPING RELEVANT GAME CONTENT

The potential benefits of computer interaction for people with autistic spectrum disorders have been discussed at length in the related work section. To recapitulate, a virtual environment scenario can be designed to help a child cope with a certain sensitivity. For instance, an uneasy sound can be included in small increments over multiple uses to give the child a chance to gradually become accustomed to it, without the distraction of other stimuli. Other distractions can then gradually be introduced into the virtual environment at a pace that accommodates for the child's sensitivities (Sehaba, Estraillier & Lambert, 2005). Computer games applied to autistic children can also be sufficiently flexible to adapt to the specifics of each child and integrate the personal data of his/her own world. Furthermore, interactions with virtual characters can be much less intimidating for a child on the autism spectrum than real world encounters.

As listed in the section 4.1, understanding the various areas of differences experienced by individuals with autism spectrum disorders can be helpful in deciding the game design principles to take into consideration. The contribution from study of these differences will be discussed in the subsections below.

4.2.1 Game Genres and Types of Interactive Applications

Below are some suggestions about the special considerations in game design and development that need to be taken into account for the different genres and type of games that may offer learning experiences in areas that are especially hard for individuals with mild to severe symptoms of autism. Their areas on influence and effectiveness are explained in Table 1 below with reference to the characteristics of persons with ASD mentioned in section 4.1

Table 1. Types and Genres of Interactive Games and Applications

Types and Genres	Areas of Influence
Arcade Games	1. Simple rules and easy to keep up with 2. Short 3. Most easily incorporated to be used with ▪ Teaching conventional learning concepts ▪ Gestures, speech and motion detection
Role Playing Games and Live Action RPGs	1. Not directly effective through text, audio, or controller s 2. Huge potential in controller-less gaming. 3. Encourage interaction through themes of common interests ▪ A game like Dungeons and Dragons with live action ▪ Games involving special interests like trains or dinosaurs
Simulation Games and Life Imitation Programs	1. Teach social behaviors and social cues 2. Repeatable 3. Life simulation games: ▪ Model simple actions and interactions with family members. ▪ Special focus on communication and behavioral cues. ▪ Teach how to identify emotions and expressions. 4. Raising virtual pets: ▪ Encourage communication through the pet's needs 5. Vehicle Simulators: ▪ Several special interests shared by individuals on the autism spectrum

Table 1 continued

	▪ Trains, trucks, and other vehicular simulations may induce a welcome interaction. ▪ In the style of 'Life simulations' or 'pet-raising simulations' to help communication, social cues, interaction and identifying expressions. 6. Scientific Simulations: ▪ For higher functioning individuals explore specific topics: biology , ecosystems or atmosphere.
Art and Creativity Applications	Computer based applications that influence learning of artistic skills such as and those that encourage creative work can be very effective in helping the child explore and understand these areas. These can be programs that follow the following principles: 1. Programs that assist in coloring, sketching, painting or drawing with a sample to show the desired arrangement. Programs that teach concepts of art, colors and color-mixing. 2. Programs that let you explore and assist in creating abstract or dynamic objects, without any clear boundaries. 3. Programs that let you create or design items given certain tools, such as a robot workshop environment where the child can put together different metallic items to create his/her own robot.
Adventure and Action Adventure Games	Quests and exploration missions provide a helpful and positive interaction environment and pursuit of quests keeps the pace interesting and engaging. These can provide engaging game-play even for lower functioning and non-verbal autistic individuals as the interactions can be chosen to be delivered through any means that are easiest for a specific individual. 1. Simple phrases and actions exhibited by in-game characters like requesting for help, thanking the player, giving helpful in-game hints can be beneficial in teaching social interaction without the complication of other stimuli such as expressions, gestures and social cues. 2. Solving puzzles by interacting with people or the environment can also help enforce behaviors like requesting help when needed and sharing information in real life. 3. Action adventures might be more useful and helpful for higher functioning individuals in the form of time-constraint problems and challenges.

When determining the game types to be used there are several considerations that ought to be kept in mind to create ideal learning environments. These should be situations that hone in on the key areas of learning that need to be introduced, reinforced or highly encouraged in children on the autism spectrum. These areas include social interaction, expressions, behavior, pretend-play and creativity.

4.2.1.1 Game Design Considerations

In all of the genres and types of applications described above, there are several additional considerations required regarding the options available to the player, or caregiver before the game starts. These options concern content and game-play and are described in more details in the following sections related to those areas.

4.2.2 Themes, Storylines and Characters

4.2.2.1 Themes and Storylines

The special common interests mentioned in section 4.2.5 that are shared among several people with autism serve as an important place to start when considering themes, story and characters for a game. These can be used in instances such as:

- Combining special interests to create a fictional world around it that can educate about the special interest itself. e.g. a story line aboard a train that involves learning about the locomotive system, and how to operate it.

- Incorporate learning about some other matter through centering the storyline around the special interest, e.g. teaching addition through a game themed around space exploration.

4.2.2.2 Properties of Characters and In-game Props

There are certain characteristics used by Brad Littlejohn to illustrate books for children with autism (Kluth, Kluth & Littlejohn, 2010). The illustrations are mostly completed with feedback from autistic students. These are some characteristics that are to be found in these illustrations:

- Simple to no backgrounds
- Narrow palette of colors
- Minimal shading
- Flat expressions on people's faces / limited expressions at best

These characteristics would not make the characters less appealing to a normally developing child, but they will offer the child with autism a less confrontational and demanding engagement than the typical broadly smiling characters.

4.2.2.3 Other Considerations

Characters and other props should be kept at a minimum. Creating a cluttered environment or too many characters either in one frame or throughout the game may make it harder to keep up with, confusing and may possibly take attention or focus away from the primary purpose within the game.

Options should be provided for changing the characters providing more than one character and theme option when possible. The most effective way is through using the most common interests to create a repository of available choices. These will surely not cover special interests of all the people on the spectrum, but there are enough commonalities between the likes and dislikes in this regard to make this a positive feature.

The options to change characters or themes should be made available at the start of the game so that they do not interfere with game-play and can be easily set up at the beginning by a parent or care-giver.

4.2.3 Game Environment (Look Development)

The designing and development of a game environment can normally follow the typical development pipeline with special consideration to certain areas that might influence the game's effectiveness and usability. These are detailed in Table 2 below with reference to the difference in perception and communication for individuals with ASD mentioned in section 4.1.

Table 2. Game Environment Considerations

Characteristics that would Influence Game-Play	Special Considerations for Game Design & Development
Visual Sensitivity: ▪ Brightness and color ranges ▪ Blinking/ flickering colors or texts	1. Muted colors and narrow palettes for all resources which include: ▪ Characters ▪ Backgrounds ▪ Special Effects 2. Additional options may serve useful in both cases ▪ Hypersensitivity towards specific colors ▪ No visual sensitivities 3. Offer choices within color palettes and brightness values with the following in mind: ▪ Narrow dynamic range within each palette ▪ No specific color values are meant to be kept out 4. Backgrounds are most effective when left blank or given a plain solid color. 5. Special effects can be distracting, over-stimulating or confusing. Suggested alternatives include: ▪ comic book style effects ▪ slowly fading effects rather than those that appear or disappear instantly
Hand-eye coordination and irregular movements	1. Avoid making in-game tasks strongly bound to precision of action 2. Options for setting the movement sensitivity at the start of the game
Colors: Identifying, memorizing and searching color	1. Do not use massively varying ranges of colors used together in a single frame. 2. Avoid using concepts that could depend too strongly on color identification or searching in any of the tasks within the game. 3. Does not mean not to challenge or teach concepts related to colors, but not to assume precision. 4. Options to choose level of color perception
Eye-Contact and Gaze direction	1. Unless the game's intent is to use facial expressions as a special interactive tool for learning, flat facial expressions should be used 2. Side characters making a request to the player ought to return to, or consume themselves elsewhere after the interaction.

Table 2 continued.

Cluttered Scenes	1. Minimal characters and background objects. 2. Sparse backgrounds and layouts 3. Use depth of field and focus transitions when needed for ▪ Reducing 'noise' (extraneous characters, background items) ▪ Helping maintain focus on the main subject within a frame.
Difficulties perceiving motion	1. Largely utilize curves instead of sharp turns or sudden direction changes. 2. Using mostly obtuse angles of turning when possible. 3. Providing 2-dimensional views of motion where possible.
Motion Sickness	1. Options to choose view of the game ▪ First person's view ▪ Outsider/ third person‘s 2. Options for angle of viewing 3. Options for camera distance from the main character.
Sensitivity to sounds	1. Avoid specific machinery generated sounds. These are generally a cause of anxiety. 2. Avoid continuous pitch (low or high), introduce a variance in pitch when possible. 3. Always provide options for separate volume control for as many game-resources as possible (e.g. game effects, dialogue, backgrounds)
Movement: ▪ Fast / Sudden motion ▪ Sudden acceleration and angular changes	1. Do not use unnatural viewing angles 2. Additional controls for specifying speed 3. Define movement speeds for characters and moving objects as a function of screen resolution to avoid speed differences when game display is resized.
Speech ▪ Limitations in speech ▪ Vocabulary ▪ Identifying objects	1. Use words to associate with objects in a scene. This should not be too hard when keeping objects within a scene to a minimum. 2. Use symbols with text to identify different actions whenever possible. 3. Avoid relying on text-only or speech-only instructions. Use both when possible.

4.2.4 Game Intent and Mechanics

The typical game modes and mechanics apply to any games created especially for children on the autism spectrum as well. However, the special characteristics that can be considered important with regards to game mechanics and intent are discussed in this section.

4.2.4.1 Pattern Recognition

The superior abilities of children with autism in pattern recognition provide an opportunity for using it with several visual content. As mentioned in section 4.1.4.2, research shows that the abilities in this area are not limited to visual perception or geometric patterns, but are also predicted in areas of spatial perception, speech, vocabulary and other sensory perception. This in turn can be used to encourage learning of concepts from various subject areas. Using patterns and designing tasks around the use of these abilities, such as:

- Reproduce certain patterns
- Design their own patterns
- Convert patterns from one to another
- Identify a common underlying pattern in different series
- Combine two or more patterns to create new ones

There are several subject areas where concepts similar to these can be used to reinforce learning and identification. Some basic areas in which these tasks can be used for distinguished include:

1. Color patterns: to reinforce identifying, searching and remembering colors. The colors can be labeled for easy memory.
2. Word patterns: to explore language, different word roots and common patterns within words. discovering new words.
3. Number patterns: Identifying, learning and designing number series and patterns. This can be extended further to include other mathematical concepts within series like multiplications, divisions, common factoring etc.

4.2.4.2 Using Text and Symbols Related to Actions, Items and Concepts in a Game

For people on the autism spectrum, understanding of the world around them is substantially different from the way most normally developing children perceive it. Representing objects, items, concepts and actions through some basic, recognizable symbols gives them an opportunity to create a connection with concepts that they cannot understand normally. (Grandin, 2006; Andrews, n.d.). This symbolic linking has been reported by several people on the autism spectrum to have helped a lot along the way in learning complicated concepts.

4.2.4.3 Defining Game Rules to Mimic Problems Encountered in Real-world Situations

Children with autism struggling to read social situations and figuring out social norms have found that one way of learning to cope with this is to relate the situation to something else that they are passionate about. (Kluth & Schwarz, 2008).

4.2.4.4 Path Following, Mazes and Puzzles

Due to the advanced spatial abilities of children with autism, games involving maps, path following and puzzles that make use of spatial thinking can achieve high responses from the children.

4.2.4.5 Other Considerations

Children with autism need to be encouraged (not directed) in order to keep attention, and the tasks must be seen as solvable by the child. (Jordan & Powell, 1990).

Although the most effective player modes may be cooperative play or multiplayer, they should not be limited to these. A game may have much to offer even in a single player mode through interactions with on-screen characters.

When applicable and possible providing an option to the parents or care-givers to control the in-game character's actions during the game can be very helpful. The features to be made available for control could include speech and actions. This could give the parents a chance to style the application and characters around their child's learning and development requirements.

Giving options to add /edit pre-programmed speech and actions from within a character's vocabulary / inventory may also serve useful in making a program specialized towards the child's learning requirements.

4.2.4.6 Game-play and Interaction Suggestions

Based on the information presented in the above sections about developing relevant game content, the interactions within a game can be designed in many different forms, such as:

- Child creates response in pet (such as: child tickles the pet → the animal giggles in response, child pinches the pet's tail → pet jumps away, child strokes the pet's head or belly → the animal purrs / wags its tail in response)
- Child causes pet to interact with objects (such as: child taps a food item on screen → pet eats it, child taps at a toy on screen → pet fetches it/plays with it)
- Character mimics child's facial expressions
- Character appears sad → child has to feed / pet the character
- Character appears happy → child can talk to character / play / interact with it
- On-screen character mimics child's speech
- On-screen character responds to specific words (such as: 'play', 'hide and seek', 'jump rope', 'catch', 'eat', etc.)
- Playing a game where child has to copy an animated character's gestures (like a 'Simon says' game, or a game to mimic dancing or workout moves)
- On-screen environment responds to child's speech (such as requests to change colors, sizes and types of objects on screen)

- Playing games like catch or tennis with computer or other players on the screen through gestures (like games played using the Xbox Kinect or Nintendo Wii)

4.3 USER INTERFACES AND DEVICES

Some of the newer technologies that may have a huge impact on gaming interfaces with regards to autism such as touch-screens, gesture and speech recognition, have started becoming more and more easily accessible to the average person recently. The interface devices available for use with gaming systems today have come a long way and are approaching closer and closer to imitating natural interactions every day. However, there has been little research involving their usability with regards to individuals with autism so far. The only technology that has been given some reasonable exposure in this regard, as covered in the previous work in section 3, is the immersive virtual reality system. The interface technologies and devices that are most highly suggested to be considered are the following:

- Touch screens
- Facial-expression recognition
- Gesture recognition
- Speech recognition

Since using game controllers, computer keyboards and mice still remains one of the most easily available options, they cannot be disregarded so easily, and do still have

potential in hand-eye coordination tasks. However most of these have the potential of taking away focus and causing game-play to become confusing.

However, it is important to take into account the special considerations regarding speech, movement and hand-eye coordination with any of these systems or platforms. As mentioned in section 4.2, the systems must provide enough flexibility in their usability to accommodate for cases such as child with little or no speech or a child with movement limitations.

4.4 GAME-PLAY MODELS

The guidelines detailed earlier all focus on improving learning environments and helping encourage interaction and social development. However, given the different levels of sensitivities and differences experienced by the people on the autism spectrum, it is suggested that the game-play model should be as accommodating for the diversities as can be. There is yet another area of learning that involves assisting the child with sensory differences learn to cope with the sensory overloads. This is also an aspect of learning that is approachable through the use of games. Here are three types of game modes/models that could be considered to help improving and increasing a child's tolerance for sensory overloads:

4.4.1 Theme-Based Model

The user is simply given a choice of a few different themes before starting the game. The themes vary from ones that use sparse sceneries, low dynamic range colors

and dampened sounds to ones that use busy sceneries, high dynamic range colors and normal-to-high volumed sounds. Thus, producing a small spectrum of themes that have visual and audio elements that incrementally increase in intensity from theme to theme. But, once chosen, the theme remains the same throughout the game.

4.4.2 Incremental Model

The user starts the game with sparse sceneries, low dynamic ranged colors and dampened sounds and as the game progresses, the characteristics of the assets gradually 'upgrade' to busier scenes and plots, higher ranged hues, brighter colors and un-dampened sounds. This can carry on throughout the game with the final few levels or stages of the game having the properties of the highest-end theme from the previous theme-based model. The gradual increments are meant to help desensitize the users to their sensitivities. This game type can also have an initial theme selection option, like in the previous model, so that the user isn't forced to work his/her way through one of the starting or intermediate themes if they don't want to.

4.4.3 Adaptive Model

The user starts the game the same way as the previous (incremental) model, with a sparse theme, but the game introduces increments along the storyline based on user feedback. The game introduces just one element of the next theme on the theme spectrum (like the spectrum created in the theme-based model), and if the user attempts to explore the asset that displayed the 'upgraded' characteristic, then more and more

elements of this next theme are introduced into all the assets gradually. This way, the game would also have an added property of being visually and audibly different if different choices are made by the user along the way.

4.4.4 Some Special Design and Development Considerations

There are several aspects within the game design and development pipeline that would be affected from the models defined previously. However, not all these effects can be preempted and would emerge based on the design and technical requirements of the game. Some examples of possible effects are shown in Table 3 below.

Table 3. Development and Design Implications for Game Models

Implications for Game Artist	Implications for Game Developer
1. Create rules to define palettes, intensity and sound levels for each theme. 2. Define rules to decide transition between the levels for each theme based on the rules defined. 3. Create a lined version of each asset that would remain the same for each theme. 4. Define coloring schemes for assets which change based on theme as follows: 5. Create rules to define a color palette with varying dynamic ranges for each theme. ▪ Create the color palettes based on the rules. ▪ Define rules to map colors of each asset from one theme's palette to another.	1. Create variable game environment and lighting for each theme based on the intensity and saturation from game designer. 2. Develop separate structures for each theme based on colors, sound and intensity levels 3. Initialize a single instance of each asset which is accessed by the structure that defines the themes 4. Define separate properties for the assets within each theme-structure using the rules color, sound, intensity rules laid out in the design phase.

In all these models it is important to keep in mind that the game durations and playability options need to be kept as flexible as possible in addition to the thematic adaptations.

5. EVALUATION AND CONCLUSIONS

Given the related work in the area and overall design of the few other existing games and interactive applications, this study introduces a new area of exploration. For the most part, effectiveness of this study would have to be tested through the implementation of these design guidelines in a interactive application or computer game. Such an application was not part of this study because the requirements involved in using human subjects, especially children on the autism spectrum, for testing an application in this area would have been beyond the scope and time constraints of this thesis.

5.1 SURVEY DETAILS

However, to carry out an evaluation for this study an online survey was conducted to investigate the effectiveness of some of the features suggested in these guidelines using some existing applications and games as a sample. Since the game design characteristics presented here do not currently exist in an application all together, examples of similar characteristics were provided from different games, applications and platforms that utilize a feature or interaction proposed here. The survey asked parents, researchers, teachers, and other care-givers of children with autism about how some features in existing games and interactive applications would appeal to their child with ASD.

The questions asked in the survey were created from the game-play and interaction suggestions mentioned in section 4.2.4.6. The points mentioned in this

section were combined with user interface device suggestions such as touch screens, speech recognition and gesture tracking mentioned in section 4.3. Some subsequent questions ask the participants about their preference in user interface devices and their usability as well as their effectiveness based on how severe the player's autistic symptoms are. These questions are formulated to gain an evaluation of the how the guidelines defining game content and interaction technologies (sections 4.2 and 4.3) are perceived to effect the child on the autism spectrum.

The survey was conducted online with invitations sent through forums, emails and social networking websites. The target participants were parents, care-givers, teachers, and researchers working with children on the autism spectrum. The results obtained from the survey are presented in the figures below.

Due to the online nature of this study, the participants were not bound to answer all questions or indicate their choices for all answer choices. So, the response counts differ among questions and among the answers choices presented with each question. An analysis of the responses received for this survey is discussed in the next section along with the conclusions regarding this study.

5.2 ANALYSIS AND CONCLUSIONS

The composition of the participants involved in this study was mainly intended to be researchers and teachers working with children on the autism spectrum, and the parents or guardians of these children. However there were considerable responses received from adults on the autism spectrum as well. This was quite likely as the survey

was carried out online through forums and networking websites, so in addition to researchers and parents, these websites are frequented by several individuals who have grown up with ASD and their responses were a welcome addition to the study results. The charts displayed in Figure 1 and Figure 2 present the statistical make-up of the participants for this study and how they learned about this survey.

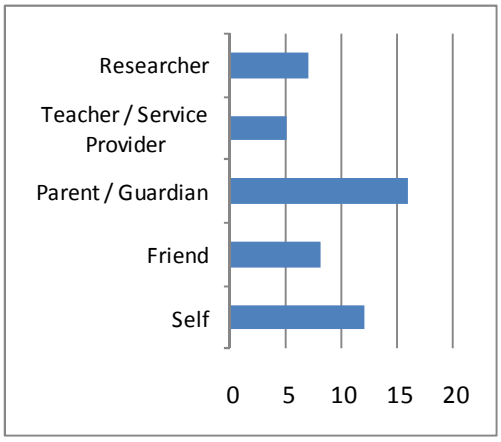

Figure 1. Composition of Study Participants

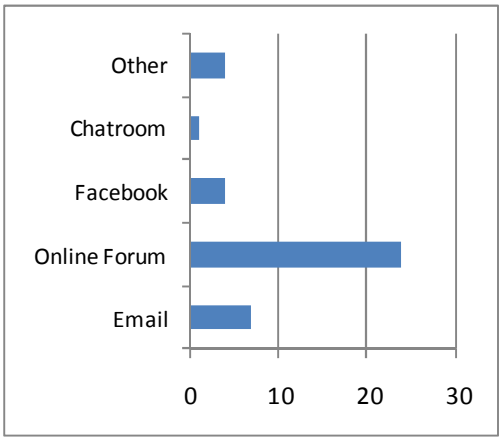

Figure 2. Origin of Study Participants

The following charts describe the questions related to effectiveness of game-play and interaction suggestions made in section 4.2.4.6 based on the guidelines in conjunction with the gaming technologies and interaction techniques presented in section 4.3. The first question along these lines asked the participants to consider interaction with an in-game character, such as a virtual pet. The participants were asked to give their opinion on how effective they think the following activities could be for encouraging interaction with this character:

1. Child creates response in pet (such as: child tickles the pet → the animal giggles in response, child pinches the pet's tail → pet jumps away, child strokes the pet's head or belly → the animal purrs / wags its tail in response)
2. Child causes pet to interact with objects(such as: child taps a food item on screen → pet eats it, child taps at a toy on screen → pet fetches it/plays with it)

These actions were suggested to be used on a touch-screen device.

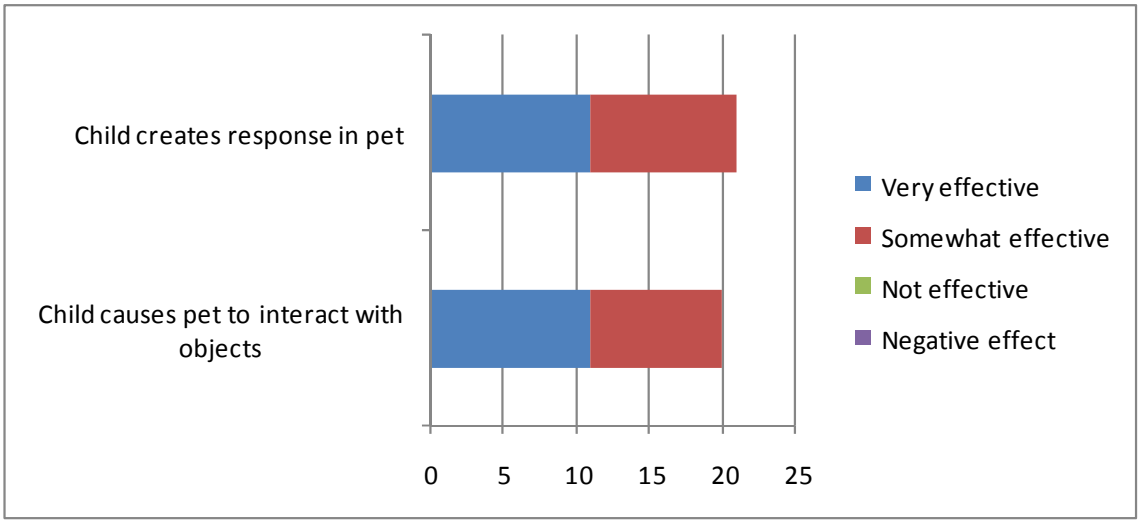

Figure 3. Interaction with On-screen Pet Using a Touch-screen

Figure 3 shows the responses received for this question. As anticipated, all participants ranked both the actions as quite effective. Out of the total responses received on this question, there was an equal spread of people choosing 'Very effective' and 'Somewhat effective'. Another question in the survey asked participants to consider a

computer game that records the actions and facial expressions of the child in front of the computer through a webcam. This game can read the facial expressions of the child. A virtual pet in the game can respond to the child's expressions (by being happy or sad with the child) or they can display their own emotions and expect a response from the child.

- Character mimics child's facial expressions
- Character appears sad → child has to feed / pet the character
- Character appears happy → child can talk to character / play / interact with it

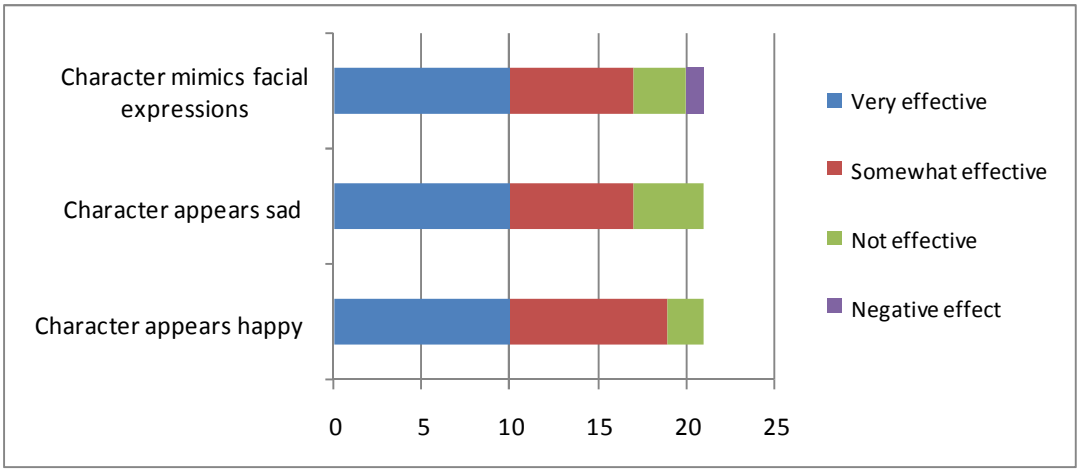

Figure 4. Interaction through Facial Expressions

The results for this question, shown in Figure 4, show that although not as successful as the previous questions about creating a response by interacting with touch, all three options of interacting with facial expressions would be considered more or less equally effective. However, there was at least one response showing that the on-screen character mimicking the child's facial expression might even have a negative effect.

There were also a few responses showing the features might not be effective. From the comments left by parents it became clear that these were from parents of children who did not understand facial expressions at all and, therefore, would be at a loss in understanding the objective of this feature in a game. This provided a very helpful insight into recognizing the additional considerations that would have to be kept in mind when adding such features to a game.

The third question in this series asked participants to consider a computer program in which a virtual character can hear and understand the speech of the child and interact with actions such as the following:

- On-screen character mimics child's speech
- On-screen character responds to specific words (such as: 'play', 'hide & seek', 'jump rope', 'catch', 'eat', etc.)
- On-screen environment responds to child's speech (such as requests to change colors, sizes and types of objects on screen)

As shown by the results in Figure 5, it was surprising to see many of the responses showed that mimicking speech may not be effective, while a couple of parents even marked it as causing a negative effect. Some of the reasons for these mentioned in comments were that the child severely disliked hearing his voice being played back to him. Others mentioned their child was non-verbal so they cannot see how this would be effective. However, the most predominant result for all options was that all participants believe the suggested features to be 'Somewhat effective'.

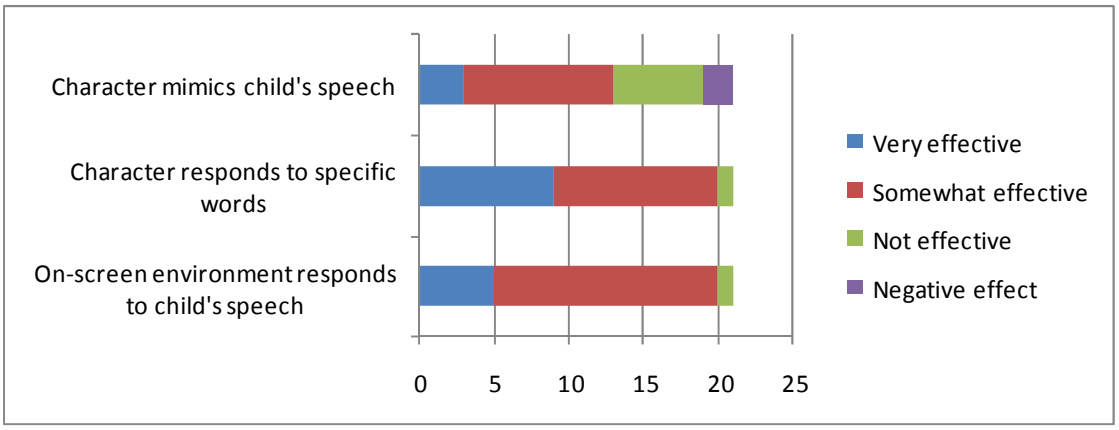

Figure 5. Interaction through Speech

The most desired option was for the on-screen environment to respond to the child's speech, of the total 21 responses received on this particular question, 10, 11 and 15 chose the features mentioned respectively to be 'Somewhat effective'. Even though the results here were somewhat contrary to what was expected (mimicking speech was anticipated to be the most desired option while the others were expected to be just average), these results and comments from parents were very helpful in realizing these differences as factors that would influence the game design.

The next query in the survey asked questions about some game-play examples in relation to gesture-recognition devices. The participants were asked how effective they think the following types of activities could be in encouraging the child's interaction with on-screen pet or with other people playing the game with the child:

- Playing with a character where the child can pat or tickle it through gestures
- Playing a game where child has to copy an animated character's gestures (like a 'Simon says' game, or a game to mimic dancing or workout moves)

- Playing games like catch or tennis with computer or other players on the screen through gestures (like games played using the Xbox Kinect or Nintendo Wii)

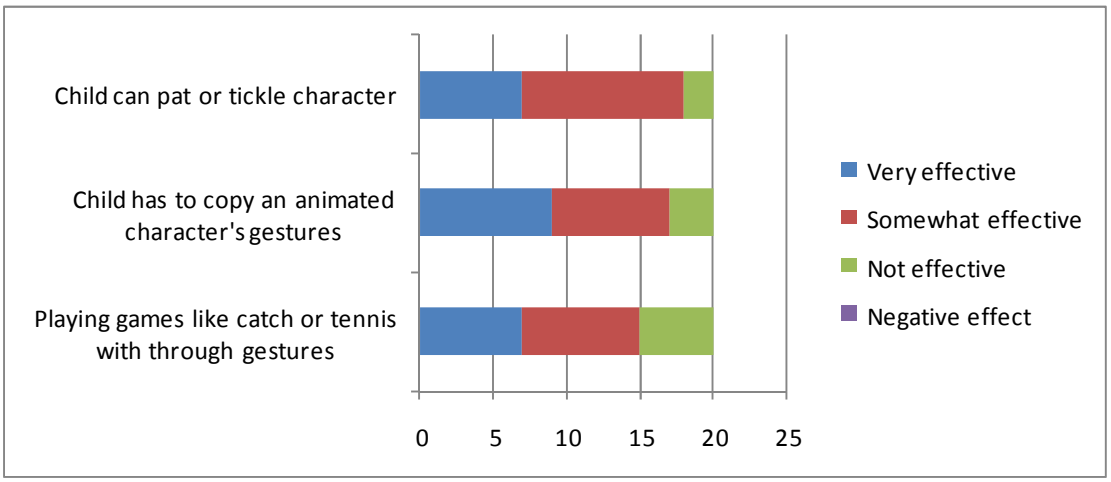

Figure 6. Interaction through Gestures

The results, shown in Figure 6, showed the actions to be overall well-received by the participants. All the game-play suggestions presented were ranked mostly between 'Very effective' and 'Somewhat effective', with none of the responses showing there could be a negative effect. This was anticipated, as mentioned in the game type examples and game mechanics suggestions provided in sections 4.2.1 and 4.2.4. However, it is most encouraging for the course of this study to note that all choices received a considerable number of responses in favor of them being 'Very effective' as compared to being 'Not effective'. Out of the total 21, there were respectively 2, 3 and 5 responses that showed the three game-play suggestions mentioned above to be 'Not

effective'. While the comments left by some participants showed a lot of enthusiasm towards gesture-controlled games such as those on the Wii or Xbox Kinect, One of the comments even stated that using gesture-controlled devices have immensely improved their child's physiotherapy activities.

As a final question in this series of questions the participants were also asked to rank devices and technologies considered to be ineffective. These questions were included in order to make sure that not only the responses related to guidelines proposed in this paper were evaluated, but the material presented in the previous / related work sections was also in agreement with the assumptions on which the outlines presented here were based on. As shown in Figure 7, the participants were asked to provide their opinion on the effectiveness of the following hand-held controllers and immersive systems for easy interaction with the virtual pet or virtual environment in a computer application or game:

- Using game-pad or joystick controller to move character around the screen
- Using steering wheel controller to steer an automobile character (truck, train or airplane) on the screen
- Toy gun controller to shoot items on the screen
- Using a computer keyboard to move character around & interact with environment
- Using a computer mouse to move character around & interact with environment
- Child wears goggles to view 3D scenery on a wall-sized screen

- Child wears a metallic helmet which displays a 3D scene on the inside

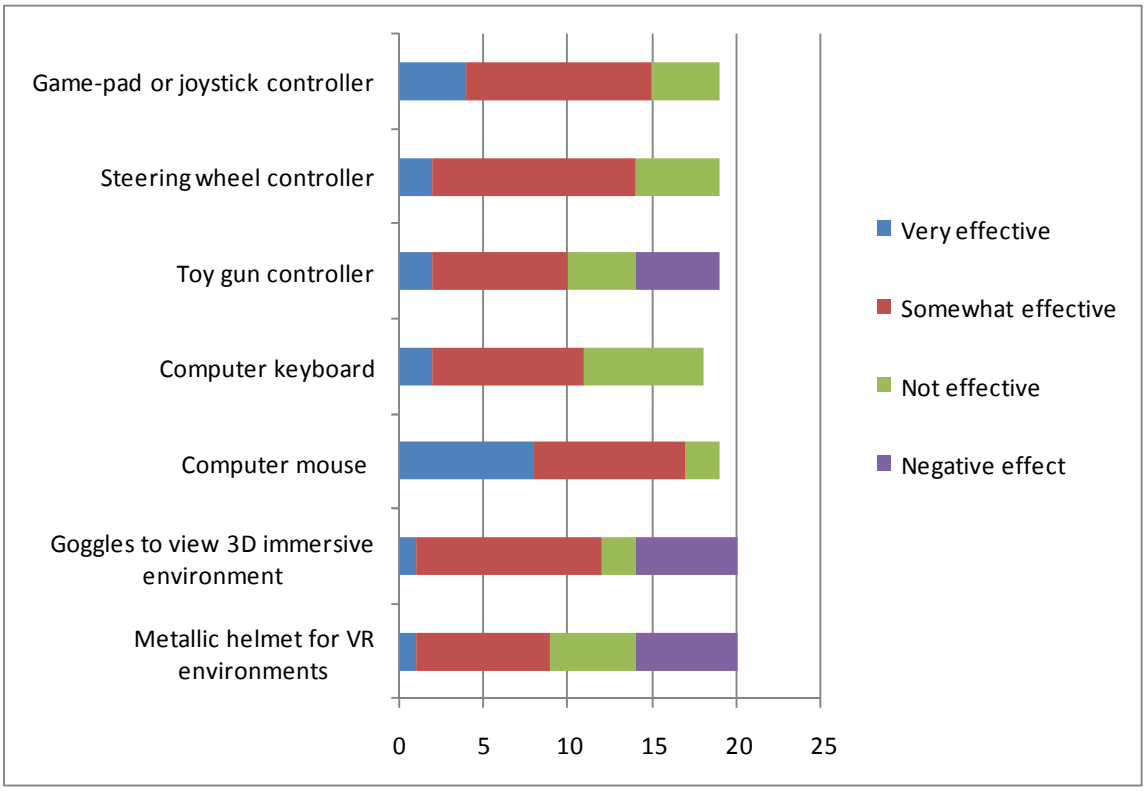

Figure 7. Interaction through Gamepads and Immersive Systems

The results received were mostly expected. However, some options, such as steering wheels, joysticks and goggles (for 3D viewing) got ranked as 'Somewhat effective' by quite a few number of people, which was not quite anticipated. But it is important to note that very few of the responses were in favor of any of these technologies and techniques being 'Very effective' in encouraging any kind of interaction or learning in a child on the autism spectrum. This is also shown from most comments left by parents, the hand-held controllers happen to be quite cumbersome for their child

with low motor skills and hand-eye coordination. Secondly, several participants also mentioned how it would be nearly impossible to have the child with autism to wear goggles or a helmet due to the sensory differences and overloads. These comments were expected, as also shown in the previous work in section 2. A most important finding was regarding the responses about using a computer mouse with 42% and 47% responses in favor of 'Very effective' and 'Somewhat effective'. Computer mice had not been given much consideration in designing the guidelines because of potential difficulties in accuracy for children with limited hand-eye coordination and motor skills. However, this response does not necessarily present a huge appeal for this particular device, but may have been due to the predominant ease of accessibility. Nonetheless, it is important to consider the possible usability in this case as well.

For the next section of the survey was carried out to gain some insight into the usability and comparability of the different gaming technologies. Individuals on the autism spectrum often encounter several kinds of stress, such as Visual Stress (panic or anxiety caused by lights, glare, colors, patterns or high contrast), Sound-related Stress (panic or anxiety caused by loud car/truck engines, lawn mowers or any other loud equipment) or Movement-related Stress (nausea, disorientation or anxiety caused by certain kinds of movements). So the next question asked the participants how beneficial they think computer interactivity might be for individuals who encounter the following stress characteristics:

- Child benefits from computer-based interaction
- Child does not benefit from computer-based interaction

- Unsure
- Child has negative effects by interaction with computers

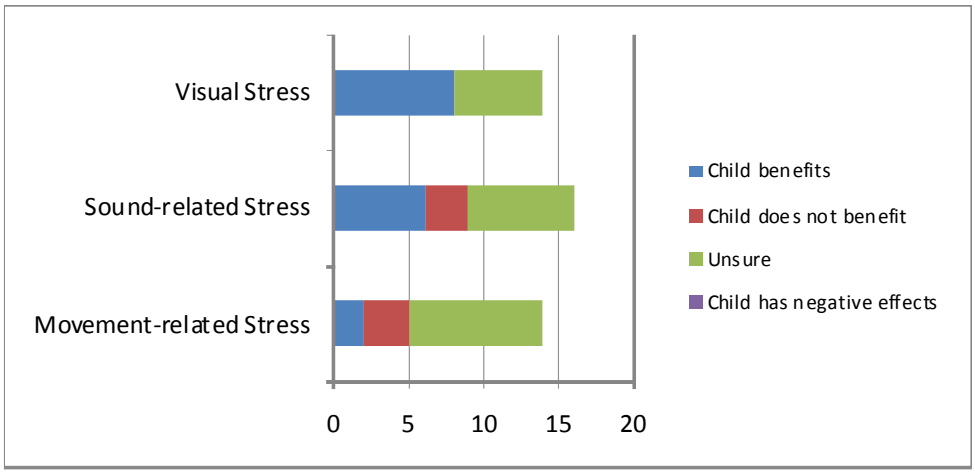

Figure 8. Computer Interactivity for Various Stress Characteristics

The results showed that a majority of participants were in favor of computer interactivity being 'Very effective' and 'Somewhat effective' in being beneficial for children with visual and sound-related stresses. But, as shown in Figure 8, 6 out of 14 and 7 out of 16 people also showed they were unsure of the benefits. The possible explanation could be a lack of exposure of most care-givers to computer-based interventions. As far as movement-related stresses were concerned, people were mostly unsure about the benefits of computer interactivity, with 9 out of 14 people showing they were unsure. The results pertaining to visual and sound-related stress were very encouraging for the purposes of this study, although a little surprising because it was possible that most people would be more worried about visual overloads through computer interactivity rather than other forms of stresses. As for movement stresses, the

participants' hesitation may possibly be a matter of a lack of exposure to devices such as gesture recognition that allow for enhancing movement skills and could be useful for reducing movement-related stresses. It is hoped that as more and more people are exposed to gesture interactions with on-screen characters and environment, people would eventually become more sure about their benefits. Nonetheless, this is a matter to be further investigated through future testing and experimentation in this area.

The next question in this section of the survey asked participants to compare the different interaction techniques available for use in gaming technologies. This was due to the fact that although gaming technologies and user interface devices have been studied in relation to children with ASD (as examined in the related work in section 2) there have been few conclusive or comparative studies to belie the usability and effectiveness of one interfacing technology or device from another. The most researched technology, covered in the prior work section as well, is the use of immersive / virtual reality systems, and have been found to be of little use. The technologies and input devices examined in this section included:

- Touch-screens (hand-held devices)
- Game-pads and controllers (joysticks, steering wheels, toy-gun controllers, computer keyboards and computer mouse)
- Facial expression recognition
- Speech recognition
- Gesture recognition

- Immersive virtual reality systems (those displayed on a screen and experienced through 3-D goggles, those displayed inside a special 3-D view helmet)

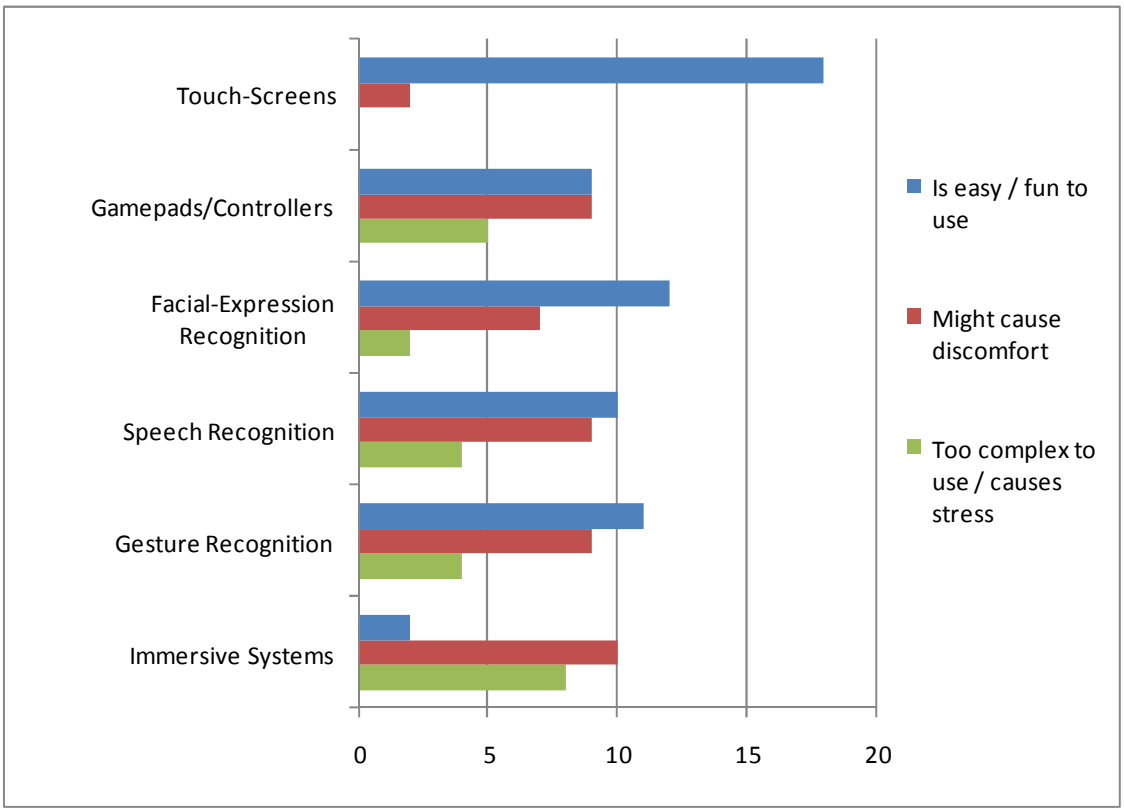

Figure 9. Usability of Various Gaming Technologies

It was expected that the results, as shown in Figure 9, showed touch-screens to be by far the most desirable mode of interface with 15 out of total 16 responses indicating them to be the easiest to use and only 2 responses showing them to possibly cause discomfort. The next interfaces that came closest to touch-screens are facial-expression recognition and gesture recognition with 10 responses each saying they are 'easy / fun to

use'. The speech recognition systems also follow close behind with 9 votes. However, these systems are also show almost an equal number of people also saying that these 'might cause discomfort'. This however does not mean that these systems should be avoided altogether. As pointed by some participants themselves, the system may cause discomfort, but could still be easy/fun and most importantly, beneficial. The discomfort may just be due to the child's general unease with social interactions. Whereas these systems would still be a beneficial tool in encouraging interaction, as is indicated by the positive responses.

Lastly, the final question of the survey attempted to examine the effectiveness of these same technologies based on the level of autism symptoms experienced by a child on the autism spectrum.

The participants were asked for their opinion on which type of individuals would likely benefit from the interaction methods discussed earlier:

- Individuals with mild autism symptoms
- Individuals with severe autism symptoms
- Neither

Figure 10 shows the responses received for this question. As shown, the responses are not very positive for individuals with severe symptoms with respect to most technologies. However, touch-screens are again considered to have an equally positive potential for both mild and severe cases of autism with 13 out of 16 participants ranking touch-screens as beneficial for both mild and severe cases of autism.

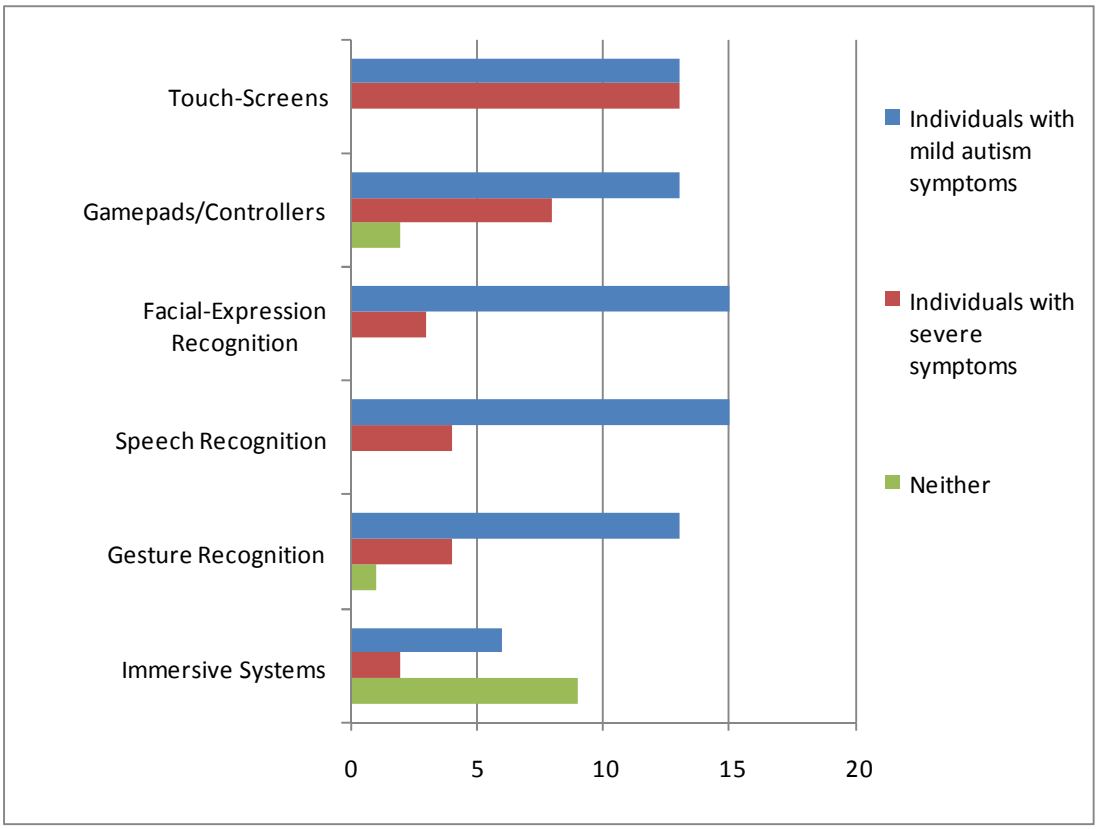

Figure 10. Effectiveness of Computer Interaction at Different Levels of Autism

The responses received for benefits to children with severe symptoms of autism are a little sparse, yet not altogether discouraging, with the most responses in favor of touch-screens and gamepad controllers benefitting a child with severe ASD symptoms. While this may be counter-intuitive to the results received for children with mild symptoms as well as to the ideas presented in this study, it may once again be a matter of a lack of exposure to much of the devices other than touch-screens and gamepad controllers. This is another special aspect to be considered for future work in this area.

5.3 CONSTRAINTS AND LIMITATIONS

There were several constraints and limitations encountered during the process of this study. As shown by related work in this area as well as by the results of the survey in the previous sections computer based interaction are a means of introducing intervention methods that have huge potential for encouraging learning and enhancing skills in individuals on the autism spectrum. However, the research in this field is still limited. The reasons range from limitations in the awareness of the autism spectrum to the understanding, awareness and accessibility of some of the most recent technologies and techniques that are available for use with computer-based applications and gaming systems discussed in this paper (such as gesture tracking, speech synthesis and adaptive gaming).

The initial methodology for this study involved development of a game demo that would incorporate the guidelines presented here. But the validity of such an application would not be confirmed without carrying out a clinical testing process. However, there were considerable difficulties arranging for such a testing process because of the requirement of involving children with ASD in the study. It would also entail certain risks considering the special needs of the participants involved in such a study. Nonetheless, the most significant hurdle in arranging for such a study was receiving feedback and interest from parents/guardians and other researchers for the sake of carrying out a proper study in this regard. The amount of time involved in gaining acquiescence from a large enough sample size to carry out a successful evaluation of this kind could not be accommodated within the timeframe of this research.

Some other constraints that effected the current study were limitations in the sample size for the survey. The study was carried out online so as to make it available to a wider range of people. However, the sample size of participants was still not large enough to carry out a quantitative analysis of the study, so the analysis presented here is only a qualitative one. A quantitative analysis would have been useful in carrying out a detailed examination based on differentiation between the responses received from researchers and those received from care-givers. Lastly, there were also the inherent limitations of an online survey which owing to the fact that there is no way to make sure who may be responding to the survey. Therefore, there was no way to verify the identity or validity of the responses.

6. FUTURE WORK

The future direction for this research would be to conduct a more formal and rigorous study of this research and thereby employing the guidelines into an interactive application or a computer game. These guidelines for designing interactions in games can also be used to design interactions for electronic or robotic toys and other physically active devices to address the physical movement requirements for children or adults with autism. Moreover, in further expansion of this idea, electronic devices nay eventually be a much more effective tool for assisting a child with ASD if the device can be fashioned into toys which would be more appealing to children to play with and easily carried around.

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