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Research paper

Designing a Serious Game for Children with Autism using Reinforcement Learning and Fuzzy Logic

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Abstract

Autism spectrum disorder (ASD) is a collection of inconstant characteristics. Anomalies in reciprocal social communications and disabilities in perceiving communication patterns characterize these features. Also exclusive repeated interests and actions identify ASD. Computer games have affirmative effects on autistic children. Serious games have been widely used to elevate the ability to communicate with other individuals in these children. In this paper, we propose an adaptive serious game to rate the social skills of autistic children. The proposed serious game employs a reinforcement learning mechanism to learn such ratings adaptively for the players. It uses fuzzy logic to estimate the communication skills of autistic children. The game adapts itself to the level of the child with autism. For that matter, it uses an intelligent agent to tune the challenges through playtime. To dynamically evaluate the communication skills of these children, the game challenges may grow harder based on the development of a child's skills through playtime. We also employ fuzzy logic to estimate the playing abilities of the player periodically. Fifteen autistic children participated in the experiments to evaluate the presented serious game. The experimental results show that the proposed method is effective in the communication skill of autistic children.

1. Introduction

Autism spectrum disorder (ASD) refers to a group of complex neurodevelopment [1, 2]. It is famous for influencing social and communication skills. The unification of gene changes or environmental causes may affect early brain development. The emersion of signs of autism is mostly at two or three years old despite being founded during the early brain development period. The most important part is the rising prevalence of ASD. The published data in [3] reports that approximately 1% of the world's population is suffering from ASD [3]. Moreover, a recent research work in [4] reports one ASD infant from every 68 early-born children. People with ASD may be talented in many areas such as arts, math, music, and visual skills but they have no independence even in adulthood. Autistic people have repetitive behaviors and steady interests [5, 6]. Technology is used in the recognition and treatment of autism. Learning via playing for autistic children is an approved way [7]. The efforts of psychologists focus on the training and improvement of applied autonomy skills [8]. Experts in the ASD field are increasingly merging technology in the sessions performed by autistic people, as using technology improves autonomy skills [9]. The researchers also display that autistic children are good at learning visually [10, 11].

Along with the traditional therapy methods, the technological approaches proposed for treating ASD children can be divided into software and hardware solutions. The hardware solutions intend to address the progress of toys or robots that can help autistic people to improve their social skills through interacting with them [12]. The target of most software systems is to distinguish emotions [13] and boost communication skills [14]. Moreover, some efforts are focused on improving video games designed for autistic people [15, 16]. To this end, serious games designed for treatment had planned to be either touchless or video games requiring any instrument. Although various research and games are designed in this context, there is still room for improvement. For example, the majority of games have been using costly appliances, which are not available for every family. These games are minimalistic, and there is room to design more complicated and entertaining games for the children.

In this paper, we propose a novel serious game called SmartBird. The appliances needed for playing this game are a laptop or a home computer set with a keyboard. We extract some features of the user's playing for further evaluation. The system uses those features and fuzzy logic to determine the player's level. SmartBird adapts itself to be at the same level as the player's skills so the player would feel the challenge at every moment.

To tune the difficulty of the game, SmartBird uses reinforcement learning methods. It aims to make treatment sessions more interesting using its self-adaptive behavior. There would be a need for the medical commission to validate the outcome of this application.

This is established in the previous works that video games are helpful for autistic children's learning [10, 11].

Former games were simplified and included a procedure that the player must follow. In the proposed game, we didn't apply any procedure but designed an AI agent that uses adapting behavior to thoroughly entertain autistic children during the gameplay.

Thus the child would like the game, and this would have some positive effects on the learning process. It is mentionable that adaptive behavior is proposed already, but not for autistic children.

The environment of the game designed for this article is far more dynamic, happier, and child-friendlier compared to prior works but has many limitations and could be better in the aspects of graphics and gameplay.

What we meant by the complexity of real life is about the motions and dynamics of the characters that the player should control or those characters controlled by the AI.

The sense of danger that arouses in the player by the movement of an eagle trying to catch the bird or hunters trying to shoot the bird is an example of that complexity. These dangers are what the player tries to avoid. Also the movement of objects is entertaining for these children [7].

These dynamics and gameplay would give the player good or bad rewards depending on their playing. Also the adaptive behavior of the game ensures that the game is just hard enough for the player to be entertained enough to continue playing.

The rest of this paper is organized as what follows. Section 2 presents a review of the related works. Section 3 explains the overview of the game, and estimates the player's whereabouts in the autism spectrum. Section 4 describes the game and the technologies used in the game. Section 5 discusses the measures that we take out to set up the experiments. Section 6 displays and reviews the experiments. Finally, Section 7 concludes the paper, and describes future work.

2. Related Works

We first glance at some research related to ASD, and then we discuss the probes linked to serious games layout for the treatment of autistic children.

Autism spectrum disorder is a set of multiplex disorderliness of brain growth [17, 18]. It is familiar that there are distinguished types of autism, although they are diagnosed under the identical class [19]. The cause of ASD is not explicit [19]. The symptoms of ASD include odd behavior in social interaction, communication, and imagination [20].

A serious game is generally a game designed for a primary purpose and particularly is a game designed to investigate social, educational, and therapeutic influences [21, 22]. In other words, the primary purpose of designing a serious game is to resolve an issue such as training surgeons or accelerating learning progress.

Electroencephalogram (EEG) has customary usage in the distinction of ASD or therapy stream, yet collecting neurofeedback from autistic people playing serious games that use EEG may reason disturbances [21, 22]. The identification of states of the brain may accurately and efficiently be successful. But the necessity of wearing an EEG cap makes the experience uncomfortable for the player.

Khayat *et al*. in [23] proposed a web-based adaptive serious game that aims to help children with learning disabilities. The system relies on two types of tests, including IQ and diagnosis purposes. It also targets children at the kindergarten stage and through the early stages of primary education. A. Elmaghraby *et al. in* [24] proposed a framework for integrating serious games with health data. The proposed unified framework may be used to improve life experience and generates friendlier health diagnostics and therapy.

Bartolome *et al.* [25] proposed a serious adaptive game that helps assess social competencies in children with ASD. This game had three levels of gameplay and needs the presence of a relevant specialist during the playtime. The first level contains several geometric figures. Some new elements from the prior level were added respectively in the second and third levels of the gameplay. They utilized an eye tracker to evaluate the gaze and eye movements of children with ASD.

Li and Elmaghraby [26] proposed the implication of an adaptive game for children with ASD. They collected data concerning players' characteristics via the Microsoft Kinect platform. Using facial recognition, they altered the game to adapt to the child's emotions.

Bekele *et al*. in [27] proposed an adaptive and individualized robot-mediated technology for children with ASD. This system provides some social skill practices for autistic children. This system contains a humanoid robot and a network of cameras and monitors.

The research aimed to compare the function of the humanoid robot with a human therapist. By using the cameras on the walls, the system follows the gaze of the users.

Wojciechowski *et al*. in [28] presented an assistive system designed for supporting young autistic children in their process of learning the pronunciation and meaning of new words. Their process utilized an instant repetition of pronounced objects' names when those items were met by the autistic children. The results were very positive.

Silva-Calpa *et al*. in [29] designed a tabletop game to motivate autistic children to behave collaboratively. They studied seven boys with high degrees of impairment. The game involved three stages that used the strategies of StrateCSA. The StrateCSA includes three strategies that grant means to promote the practice of collaboration among users. The first strategy inspires cooperation by recommending exercises that require resource splitting. The second strategy inspires communication by presenting duties that include resource splitting under an information exchange. The third strategy inspires coordination by offering duties that include the participant's communication via the interface's components. The results were progressing.

Sundberg researched the possible links between online gaming, loneliness, and friendship in people with ASD [30]. They examined 85 autistic adolescents and adults and a control group of 71 cooperators. Results displayed that inside the ASD sample, personalities who play online games have more friends than those who do not. The reasons for playing online games were different between the autistic group and the control group.

Covaci *et al*. in [31] proposed a multisensory educational game and studied how enabling olfaction can contribute to users' learning performance, engagement, and quality of experience. They compared the results obtained in the presence and absence of olfactory feedback on both a mobile and a PC. The results were progressing.

Mercado *et al*. [32] proposed a use case of a BCI video game designed to support children with ASD when dealing with neuro-feedback training sessions. The purpose of their game is to keep children's attention above a threshold. Their game used a BCI headset to read the user's attention. They worked with 12 autistic children through four weeks of study. The outcome of their study revealed that their game could successfully assist children with autism through neuro-feedback training sessions. Tang *et al*. in [33] researched the effects of computer-based interception on autistic people by using five serious games. They searched databases to identify 34 studies about social-emotional CBI and 17 control studies included in meta-regressions analyses. Their results displayed that serious game design policies are (45%) synthesized with social-emotional CBI for autistic individuals. They recommended that the serious game design framework has advantages in leading the development of social-emotional CBI that enhances the social-emotional abilities of autistic people.

Caro *et al*. in [34] compared two exergames, which are video games that involve physical exertion. The comparison aimed to support the visual-motor coordination of people with high-functioning ASD, the first one devised for autistic people and the second one planned for neurorehabilitation. Their study displayed that both exergames were progressing. Although, the participants delivered a higher percentage of limb movements with the exergame explicitly designed for ASD. Also, participators had more fun experiences with the exergame designed for ASD than the other exergame.

Jarraya *et al*. in [35] presented a self-acting autistic children's emotion identification system to guarantee their safety during the meltdown crisis. They compared the performance of two new ways to identify micro-expressions for composite emotions of autistic children throughout a

meltdown crisis. The first one was a geometric method that authorizes extracting hand-crafted spatiotemporal features. The second method enables eliciting and classifying deep features using the famous forms of supervised learning techniques. They displayed that their recommended method can achieve high-grade classification accuracy using *the Random Forest* classifier (91.27%) with hand-crafted features. Classifiers trained on deep features displayed more outstanding performance (97.5%) with KNN, SVM, Decision, and Naïve Bayes.
Most of the above research employs expensive technologies, which are not available for every family. Also the serious games designed in those research are very simple and might not simulate real-world dynamics. In this paper, we propose a serious game that attempts to simulate these dynamics using adaptive behavior. Using adaptive behavior, we try to make a general game that covers all of the autistic children capable of using the appliances and improving their skills.
Notably, the appliances needed for playing the proposed game are only a personal computer with a keyboard or any Android device. Sekhavat *et al*. in [36] mentioned that the hardness of the game must be at a medium level so the player receives the most promising outcomes. They also referred that manually adjusting the hardness of the game is very hard, even for a specialist.
We have recently proposed a theory that uses the adaptive difficulty in video games to achieve adaptive behavior toward autistic children [37]. Later, we devised a simplistic serious game to test the stated theory [38]. The results were promising. However, there were some significant problems. The participant's number and diversity were at the minimum. Also the designed game was still very simplistic and did not have the complexity of real life. Finally, the results were not controlled so to ensure that the game has a noticeable impact on autistic children or all children. In reference [37], we only proposed an idea but in reference [38], we designed a game and experimented with a group of autistic children. But in this paper, we added a control group and made a more complicated game. Also we extracted some new parameters and used those parameters to better survey autistic children's behavior towards the game.
In comparison to our prior work in reference [38], we added a control group that contains both genders. Also in the current paper, autistic children's diversity has grown in the aspects of gender, age, and location on the autism spectrum. It is correct that the number of participants is not large enough but we should mention that we had a permit to work only with one autism institute and only for a short period.
In this paper, we propose a game that contains a more sophisticated and happier environment. Also there were more participants with more diversity in manner of gender, age, and location in the autism disorder spectrum. Also there is a control group to compare the impact of this game on autistic children and regular children.

3. Materials and methods

In this paper, we designed and developed a serious novel game called SmartBird. The difficulty of the game is adapted to the level of the user's skills. To this end, the system uses an intelligent agent in the game, which employs fuzzy logic to identify the level of the user and reinforcement learning to adapt the game's difficulty to the obtained level. Adapting the game to the user's level helps the children to have better entertainment. Moreover, it can also help the user to improve communication skills through the game's run-time.

3.1. Overview of game

In the proposed game, the user navigates a bird. Objectives of the game are keeping the birds safe from the eagles and hunter's gunfire and preventing them from hitting the obstacles. At first, the bird has a certain amount of health. Hitting an obstacle or enemy would decrease the bird's health regarding the amount of damage that obstacle or enemy has. Figure 1 displays a screenshot of the game. Also here you can watch a video of the gameplay: https://www.droarpbox.com/s/qzyu3quz8t6ydnm/Media1.avi?dl=0.

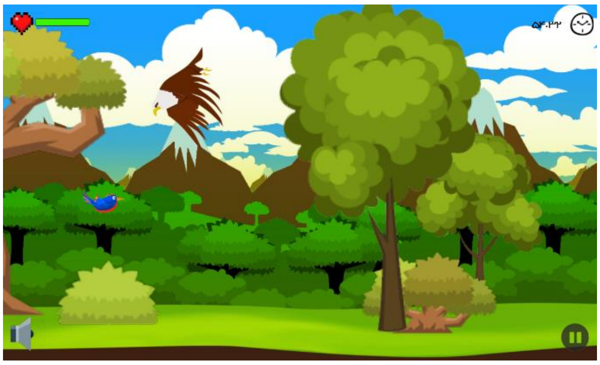

Figure 1. A scene from the SmartBird game.

During the first stage of the game, there are neither any obstacles nor enemies. During this state, the user gets to know the game's environment and how to navigate the bird correctly.

As mentioned, the proposed game equipped an intelligent agent who employs an automata machine, shown in Figure 2. This automaton displays the action space in every state. At each stage, the agent measures the user's skill level.
Using the state machine shown in Figure 2, the agent finds the most suitable action as the next state from the set of possible states, applies the chosen action, and makes the transition to the next state.
The following section displays how the game finds the best action at each state, according to the user's playing skills. Table 1 defines the notations used in this paper.

3.2 Adaptive behavior

Using fuzzy logic, the AI difficulty system estimates the player's whereabouts in the autism spectrum [38].

3.2.1 Measuring player's level using fuzzy logic

It is to be noted that the player's level (professional or amateur) is unknown due to fuzzy logic. To measure a player's skill level, we define three sets P, M, and A, denoting professional, medium, and amateur players. We also define an epoch as a 10 second of the game's time. Every epoch is divided into ten chunks. During an epoch, the intelligent agent measures the level of the user's skills of playing. To measure the skills of the user, a variable named skill factor is defined as follows [39]:

$$SF = \frac{\sum_{c=1}^{n} w_c f_c}{\sum_{c=1}^{n} w_c} where\ 0 \le f_c \le 1, w_c \le 1 \quad (1)$$

At the end of every epoch, the system updates the value of SF using (1). The such value represents the level of skills of the user during an epoch. f_c is an arbitrary function to display a user's skills during a chunk. w_c is the weight of a chunk that displays the severity of a f_c.

We defined f_c as the function of the user in the manner of preventing hitting the obstacles or enemies during a chunk and obtained using (2) as follows:

$$f_c = 1 - \frac{h_c}{(h_c + 1) \times t_c} \quad (2)$$

where h_c is the number of times that the bird hits any obstacles or enemies during the chunk, and t_c is the length of a chunk. c is the index of the current chunk.

We also define w_c in (3) as follows:

$$w_c = c \quad (3)$$

where c is the index of the current chunk in the current epoch. Note that the weight of the last chunks is greater than the first chunks. Moreover, the last chunk of an epoch is more important than others because the user had more time. Therefore, more chance to adapt herself/himself to the situation of the game.
Figure 3 exhibits the fuzzy diagram used to rate the player's skill level conforming to the SF variable [37, 38].
Using the fuzzy diagram shown in Figure 3, degrees of involvement of the user's skills to the fuzzy sets are determined by the SF variable, which displays the user's level of playing skills. Now, the intelligent agent knows the user's level, and it can adapt the game accordingly. The characteristics of the adaptive behavior are expressed in the following section.

3.2.2 Choose finest actions in every state

In this paper, we present a reinforcement learning-based technique to design our adaptive and intelligent agent. A reinforcement learning agent perceives situations and maps them to actions. Such an agent must be capable of learning from before events. To achieve the best reward, it has to find the most appropriate actions by trying all feasible actions. Typically, actions would affect the urgent reward and all upcoming rewards [37]. Markov Decision Process (MDP) is mostly used to model the Reinforcement learning issues [40]. State-Action-Reward-State-Action (SARSA) is an algorithm for the acquisition of an MDP policy [38]. As Massoudi *et al.* [34] explained, SARSA evaluates each state-action pair using (4):

$$Q(s_{t-1}, a_{t-1}) = (1-\alpha)Q(s_{t-1}, a_{t-1}) + \alpha(r + yQ(s_t, a_t)) \quad (4)$$

At each time step *t*, the value of a state-action pair $Q(s_{t-1}, a_{t-1})$ is determined. s_{t-1} is the last state of the agent, and a_{t-1} is the action it chooses at that state.
In *SmartBird*, r is the difference between the current health of the bird and the health that the bird had during the last epoch r is gained from (5).

$$r = health_{current} - health_{last} \quad (5)$$

Depending on the user's skill level, the probability of selecting a certain action would be diverse. For example, the probability of choosing a valuable action against a professional user is greater than the probability of choosing a low-value action.

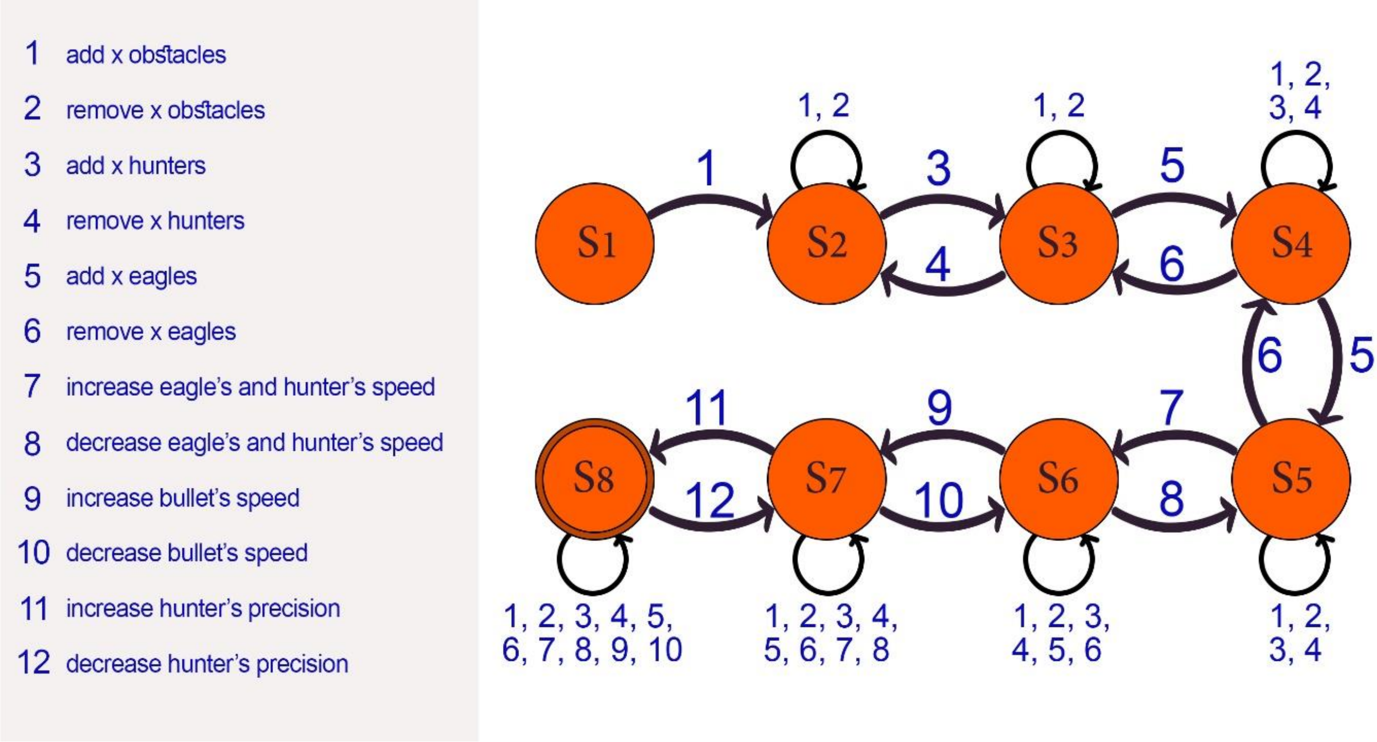

Figure 2. Automata machine used in the intelligent agent of the proposed game.

Table 1. Table of Notations of this research work.

Notation	Definition
SF	Skill factor, a parameter to measure the skills of the user
c	index of the current chunk in the current epoch
w_c	Weight of a chunk
f_c	Function of the user in connection with preventing hitting the obstacles or enemies during a chunk
h_c	Number of hits to obstacles or enemies during a chunk
t_c	Elapsed time during a chunk
t	A time step
st	Current state at time step t
at	Selected action at time step t
γ	$(0 \le \gamma \le 1)$ is a factor that exhibits the impacts of upcoming actions on the determination of the value of every state-action pair
r	Urgent reward that the agent receives from the environment
Q	value of a state-action pair
α	$(0 \le \alpha \le 1)$ is the learning rate that indicates the effects of the agent's prior experiences
H	Stands for hard difficulty level
M	Stands for medium difficulty level
E	Stands for easy difficulty level
P_H, P_M, P_E	The probability vectors corresponded respectively to hard, medium, and easy difficulties
P, A, M	Fuzzy sets. respectively stands for professional, amateur, and medium
μ	Degree of involvement of a parameter to a fuzzy set

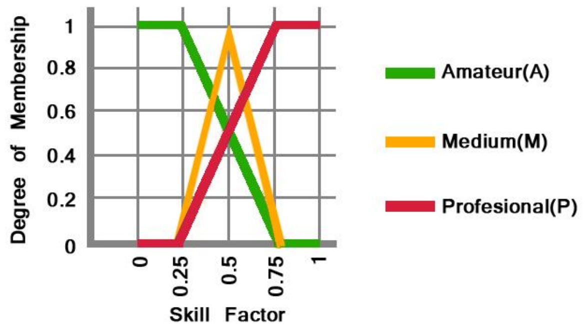

Figure 3. Fuzzy diagram displays the player's degree of involvement in each set [37, 38].

Also the probability of choosing a low-value action versus an amateur player is greater than the probability of selecting a valuable action. Thus action-choosing chances at every state are computed based on their values to achieve a method that can produce enough variety of selecting actions.

The probability of possible choosable actions at each state is specified using three probability vectors. Elements of the first vector, $\overrightarrow{P_H}$, is calculated based on (6):

$$P_H(s,a_i) = \frac{Q(s,a_i)-(m_i-\varepsilon)}{\sum_{k=1}^{n}(Q(s,a_k)-(m_i-\varepsilon))}$$

$$.where\ m_i = Minimum \quad (6)$$

$$.(Q(s,a_1),Q(s,a_2),....,Q(s,a_n)),\varepsilon>0,a_i\in A_s$$

$$.,A_s\subseteq A, i=1,2,3,...,n$$

m_i is the set containing feasible actions of state s and the set of all actions in the agent's state space is displayed using notation A. Based on this equation, the possibility of selecting the higher valued actions is premier.

The reason for adding ε is to let the agent also select the actions with lower value along with higher valued actions.

To minimize the impact of this on the possibility of selecting higher valued actions, it is recommended for ε to has a small value but greater than zero. Choosing it to be zero will lead to a division by zero error [39].

$\overrightarrow{P_E}$ chooses the lowermost values with premier probabilities. Elements of $\overrightarrow{P_E}$ are computed based on (7):

$$P_E(s,a_i) = \frac{(m_x+\varepsilon)-Q(s,a_i)}{\sum_{k=1}^{n}((m_x+\varepsilon)-Q(s,a_k))}$$

$$.where\ m_x = \text{maximum} \quad (7)$$

$$.(Q(s,a_1),Q(s,a_2),...,Q(s,a_n)),\varepsilon>0,a_i\in A_s$$

$$.,A_s\subseteq A, i=1,2,3,...,n$$

There is a further probability vector $\overrightarrow{P_M}$, which selects its elements with equal probability at every state using (8):

$$P_M(s,a_i) = \frac{1}{n}, i=1,2,...,n \quad (8)$$

where n is the count of whole feasible actions for the agent in state s.

There is a final probability vector for every state, using (9) to achieve adaptive behavior according to the player's degree of involvement in defined sets:

$$\overrightarrow{P_{Final}} = lerp(lerp(\overrightarrow{P_E},\overrightarrow{P_M},1-\mu_A(SF)),\overrightarrow{P_H},\mu_P(SF)) \quad (9)$$

where μ_P and μ_A are degrees of involvement to sets P and A, respectively. The *lerp* function is a linear interpolation function in programming languages [39]. In Equation (9), $\overrightarrow{P_{Final}}$ displays the probability of choosing every action in the state s, according to the player's social skills [37].

4. Gaming Technology

In this section, we will discuss the game and the technologies used in the game. After that, we will demonstrate the implementation of the game.

The game is designed with the unity engine and is written in the C# programming language.

SmartBird is a 2D platformer game. The game is a third-person perspective, and the camera's view is from the side of the scene.

There are three reasons for choosing this genre and perspective. First of all, as this game is not a VR-based game, it would be hard for a child, especially an autistic one, to perceive the concept of the first person's perspective.

We thought that it is more perceptible for the player to see the main character. She can sense the effect of her pushing the buttons of the keyboard on the character's movements.

Secondly, as these children had accustomed to 2d picture training, it was more vivid to them than a 3D game or a more complex game.

Finally, developing a 2d platformer was more feasible due to the amount of budget we got.

The demonstration of the mapping of presented equations to the c-sharp code is as follows.

Implementation of state class is demonstrated in Pseudo-code 1.

Pseudo-code 1. The implemented class for a state.

```
public class State {
 list actions;
 int order;
AddActions (string action, float value, int nextStateOrder)
 {
   list ActionValue;
   ActionValue.Insert(0, action);
   ActionValue.Insert(1, value);
   ActionValue.Insert(2, nextStateOrder);
   actions.Add(ActionValue);
 }
   list GetActions () {return actions;}
}
```

This class has two attributes, a list of possible actions at the state and the state's order. This class has two methods, a getter method to access the state's action list and a method to add actions to a state. We add an initial value to each action, so the game has initial knowledge. Initial values of actions had calculated and tuned during the developing and testing phases. “nextStateOrder” argument indicates the state that is the result of doing such action.

Here is Pseudo-code 2 to initialize the states of the game based on Figure 2.

Pseudo-code 2. The initializing of the states is based on Figure 2.

```
void InitializeStates ()
{
  states[0] = new State (1);
  states[0].AddActions(“Add x obstacles”, 4, 2);
  .
  .
  .
  states[4] = new State (5);
  states[4].AddActions(“Add x obstacles”, 4, 5);
  states[4].AddActions(“Remove x obstacles”, 3, 5);
  states[4].AddActions(“Add x hunters”, 4, 5);
  states[4].AddActions(“Remove x hunters “, 3, 5);
  states[4].AddActions(“Add x eagles “, 2, 6);
  .
  .
  .
}
```

Then the game explores the first state for the next action and does that action. This is displayed in Pseudo-code 3:

Pseudo-code 3. The agent explores the best action at the first state.

```
currentAction = Exploration(currentState);
doAction(currentAction);
```

The exploitation method is where Q-values of state-action pairs had updated after perceiving the reward. The game calculates the reward and does the exploitation afterward. Pseudo-code 4 should be iterated until the end of the game.

Pseudo-code 4. The agent calculates the reward and updates the Q-values of the last state-action pair based on that using the exploitation method.

```
reward = calculateReward ();
Exploitation ();
doAction(currentAction);
```

The implementation of the exploration method is displayed in Pseudo-code 5:

Pseudo-code 5. The implementation of the exploration method.

```
string Exploration (State currentState)
{
  list actions = currentState.GetActions();
  max = Find Max (actions)
  min = Find Min (actions)
  foreach (item in actions)
        sumE += (max + epsilon) – item[“value”];
        sumH += item[“value”] - (min - epsilon);
  end foreach
  foreach (item in actions)
        PE = ((max + epsilon) - item[“value”]) / sumE;
        PM = 1 / Count (actions);
        PH = (item[“value”]- (min - epsilon)) / sumH;
        item.Insert(3, PE);
        item.Insert(4, PM);
        item.Insert(5, PH);
  end foreach
  muA = degreeOfMemership (“A”, skillFactor);
  muP = degreeOfMemership (“P”, skillFactor);
  foreach (item in actions)
        PFinal = Lerp (Lerp (item [“PE”], item [“PM”], (1-muA)), item [“PH”], muP);
        item.Insert(6, PFinal);
  end foreach
  foreach (item in actions)
        Answer =Find Max (item [“PFinal”]);
  end foreach
        return Answer;
  }
```

First, the actions with the highest value and lowest value at the current state had been found. Then using those values, Vectors $\overrightarrow{P_H}$, $\overrightarrow{P_M}$, and $\overrightarrow{P_E}$ were calculated based on (6), (7), and (8), respectively. We choose 0.1 for ε as this is greater than zero but closely near it. Using Figure 3 and Equations (1) and (2), the agent's degree of involvement toward set A and set P had calculated. Using those and (9) $\overrightarrow{P_{Final}}$ was computed and based on that state's best action.

The implementation of the exploitation method is displayed in Pseudo-code 6:

Pseudo-code 6. The implementation of the exploitation method.

```
void Exploitation () {
   float this_Q, next_Q, new_Q;
   string new_action;
   State newState = findNextState (currentState, currentAction);
   new_action = Exploration(newState);
   this_Q = getQValue (currentState, currentAction);
   next_Q = getQValue (newState, new_action);
      new_Q = this_Q + alpha * (reward + gamma * next_Q - this_Q);
   setQValue (currentState, currentAction, new_Q);
   currentState = newState;
   currentAction = new_action;
 }
```

In the exploitation method, the best action of the next state would be explored using the exploration method. Using (4) and the perceived reward, the Q-value of the current state-action pair had calculated and updated. Then the agent moves to the next state and does the explored action. The agent perceives the reward and does the exploitation method again. The agent iterates this circle until the end of the game or when the player loses. γ and α were set to 0.5 in this game, located in the middle of zero and one.

5. Experimental Setup

In this section, we discuss the measures that we take out to set up the experiments. Also we will discuss some behavioral characteristics of children.

To experiment with the proposed method, 15 children with autism played the game. These children are from both genders, twelve boys and three girls. These children are from four to sixteen years old. Also, sixteen normal six-seven aged children played the game as the control group. These children are also from both genders. Six girls and ten boys. All of the children used the keyboard to play the game.

To measure the children's skills, some parameters are required. For example, they are winning or losing the game, the total time of the game, and the game's difficulty.

We observed that these parameters are not specific to measuring the child's skills during the experiments. For example, consider a situation wherein the child, instead of flying the bird, constantly stays at a certain point for a great amount of time. In this situation, the total time of the playing grows, but there is not any profit for the child. We consider a new parameter to manage that situation. This parameter displays the quality of performance of any child based on the opinion of an expert person. The expert person rates the quality of a child's play at an interval of one to eight. With the combination of this new parameter and old parameters, Equation (10) is created:

$$P = (q^2 \times w \times s) + t \tag{10}$$

where t is the total time of playing, s is the number of the state of the automata when the game ends, and w displays whether the player won the game or lose.

In the time of loss, the quantity of w is one, and in the time of winning, it is 1.2. The little amount of win times of winning is to prevent from creating out-layer data, and this quantity is specified during the designing of the game with distinct experiments.

In Equation (10), q displays the rating assigned to the quality of playing of the player by the expert person. Eventually, P is the final point assigned to the player's skills at one time of playing.

We encountered a problem during the tests with autistic children. Some of the children were not doing great with the keyboard. Thus the bird character would stick in the same place forever. With the delay occurring in the gameplay avoiding its subsequent phases, there wasn't any attack from the enemy NPCs. Over time, the child's score increased.

The "quality according to an expert" parameter was added to resolve that problem. It is the opinion of an expert Person in the field of ASD concerning whether the player did play correctly or only stood in the same place and let the time pass. It was better to determine the mentioned quality by an AI Agent using a new algorithm containing some new parameters attributed to the quality of game playing.

The "State Welfare Organization of Iran" allowed us only to work with Autistic children for a short period. Thus to continue the research work, we compromised and used a human expert.

Also for the same reason, we had not enough time to access those children for further tests and repeat the game.

In Equation (10), q is multiplied by itself to bold the influence of the expert person's rating. Because of the effect of the total time of playing on misjudging, instead of multiplying, t is added to the other parameters.

Table 2. Behavioral parameters of participating Autistic children.

Gender	Other disorders	Age	Level of ASD	Participant
Boy	Echolalia	15	2	Patient 1
Boy	-	7	1	Patient 2
Boy	-	4	3	Patient 3
Boy	-	7	1	Patient 4
Boy	-	6	1	Patient 5
Boy	-	14	3	Patient 6
Girl	-	9	1	Patient 7
Boy	Deafness- Echolalia	16	2	Patient 8
Girl	-	15	3	Patient 9
Boy	Mental retardation	8	3	Patient 10
Boy	-	7	2	Patient 11
Girl	-	8	3	Patient 12
Boy	-	14	3	Patient 13
Boy	-	4	3	Patient 14
Boy	-	10	2	Patient 15

As displayed in Table 2, fifteen Autistic patients participated in this experiment, including twelve boys and three girls. Also three of them had other disabilities that accompanied ASD.

6. Results and Discussion

Figure 4 and Figure 5 are created based on the (10). Figure 4 and Figure 5 illustrate the children's functions with the autism and control groups, respectively. These figures show that the presented method is beneficial for enhancing the situation of autistic children. Long-term playing might increase these effects. In Figure 4, the vector that displays the average of these functions has a positive slope.

This slope shows the influence of this method in the long term.

Figure 5 displays that after one turn necessary for introducing the game to the children, most control groups did a great job.

These results demonstrate that the proposed serious game is nearly very easy and ordinary for typical children but is more effective for children with autism.

Here we analyze the function of two patients individually. Table 3 displays the function of Patient 8.

This patient is a sixteen years old boy who suffers from deafness and echolalia with level Two ASD.

This patient had not won a game. As there was not a considerable difference between the first time and the last time he played the game, the total time him playing was not an efficient parameter. Also he repeatedly left the keyboard. Therefore, as time went by, the bird stayed still at a certain point.

For the same reason, the state's number when the game ended was not a helpful parameter. But the quality of his playing was narrowly improving after three times of playing. It was reasonable for him to have such a minor improvement as he has other disorders that accompany ASD.

Table 4 displays the function of Patient 7. Patient 7 is a nine years old girl who has level one ASD. She does not suffer from any other disorders. She did not win the game. After two times of playing, the state's number at the time of the game ending and the total time of playing had improved.

Her playing quality had considerably increased after two times playing. Finally, as she was noticeably improved, the game had not sufficiently engaged her, and she was reluctant to resume playing. Figure 6 compares the function of autistic children based on their gender. Based on Figure 6, the average of the boy's operation is better than the girls.

Such results emphasize that the proposed method is efficient in both genders.

Also we must notice that the number of girls who participated in this experiment was 3, against 12 boys, so we cannot certainly say that boys are better than girls at playing this game.

Figure 7 shows the comparison between the children based on their location with autism spectrum disorder. Knowing that “level one” children have minor signs of the disorder, the fact that the children at “level two” had a better performance means that the location at the spectrum and their function at playing this game are not correlated. All of the children had approximately equal improvement during ten turns. It is also mentionable that children in “level three” had many significant difficulties working with the appliances of this research, such as the keyboard. Figure 8 illustrates the comparison between children in three age ranges. To achieve this, we divided the children into three ranges, children less than seven years old, children between 7 to 12 years old, and children bigger than 12 years old. As shown in Figure 8, children bigger than 12 years old showed better performance.

Also children 7 to 12 years old were nearly good as the former range, but children less than seven years old were not good enough. The reason is that older children have experience using the computer and playing video games. However, the improvement of the age ranges is nearly equal and positive. Figure 9 shows the comparison between children who have another disorder that accompanies ASD and children who have no other derangements that accompany ASD.

As shown in Figure 9, both groups improved during the ten turns of playing. As displayed in figures 6-9, we can say that our method has a good effect on all of the children in any situation or range.

7. Conclusions and Future Work

One of the most notable domains that are effective for people with ASD is social skills. Interacting with other people is very difficult for Autistic people. Using the stated system may help them to have a more convenient life. Also this system tries to probe how autistic children look at objects and their motions.

The proposed method uses the SARSA algorithm. Surveying and comparing this algorithm with other reinforcement learning methods would be beneficial. A few participants in experiments, the unwillingness of autistic children to continue playing the game, lack of connectivity between autistic children and the keyboard, and the limited number of turns that a child plays the game is the difficulties that were this research. We suggest doing future work in the long term with more participants.

As already mentioned, the “state welfare organization of Iran” allowed us only to work with autistic children for a short period and only with one autism institute. Thus we did not have enough time to access those children for further tests and to repeat the game.

We only had access to those children whose families were in consent about these experiments and were present during the days we were at that institute.

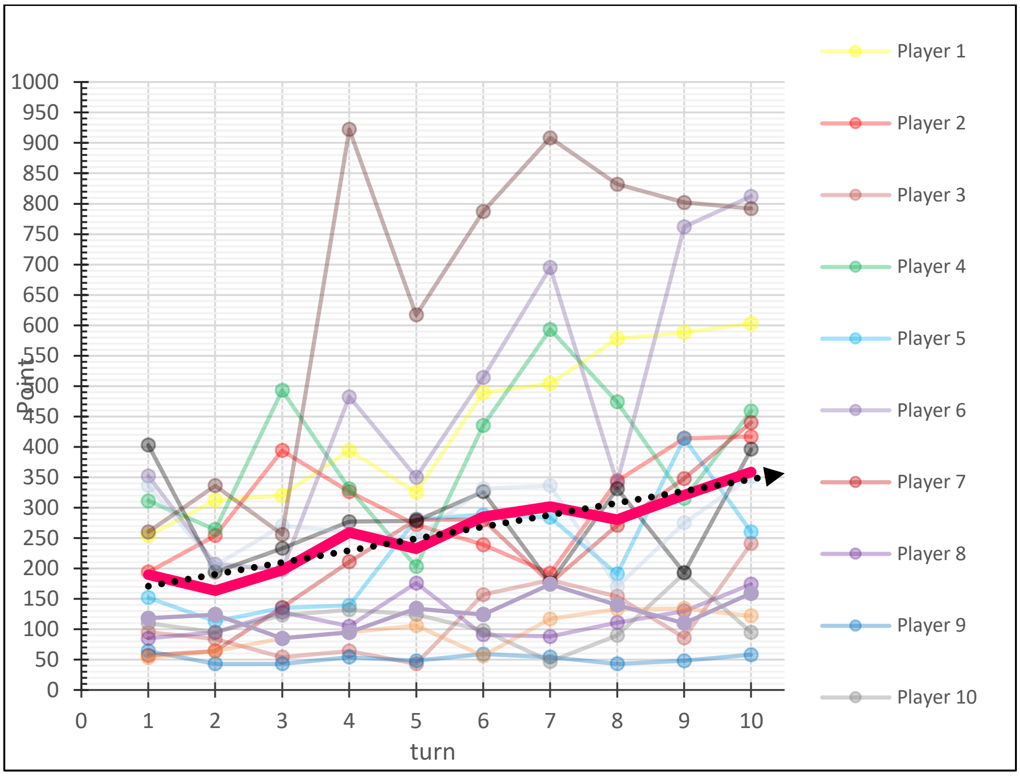

Figure 4. Operation of the autistic children in 10 turns.

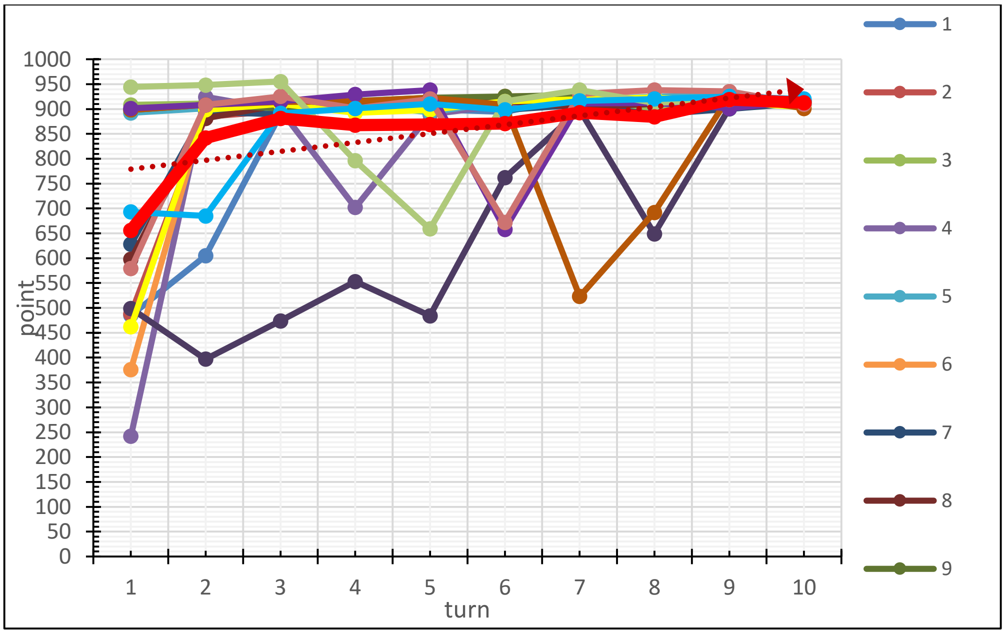

Figure 5. Operation of the control group in 10 turns.

Table 3. Function of patient 8.

Count of the game played by the player	Did the player win the game?	Number of the state of the automata when the game ends	Total time of the playing	Quality of playing (out of 8)
1	No	5	80	1
2	No	5	90	1
3	No	6	122	1
4	No	5	85	2
5	No	5	131	3
6	No	4	75	2
7	No	5	83	1
8	No	5	91	2
9	No	5	110	2
10	No	6	120	3

Table 4. Function of patient 7.

Count of the game played by the player	Did the player Win the game?	Number of the state of the automata when the game ends	Total time of the playing	Quality of playing (out of 8)
1	No	4	53	1
2	No	4	60	1
3	No	5	116	2
4	No	6	115	4
5	No	6	130	5
6	No	5	100	6
7	No	4	76	5
8	No	5	91	6
9	No	5	103	7
10	No	6	146	7

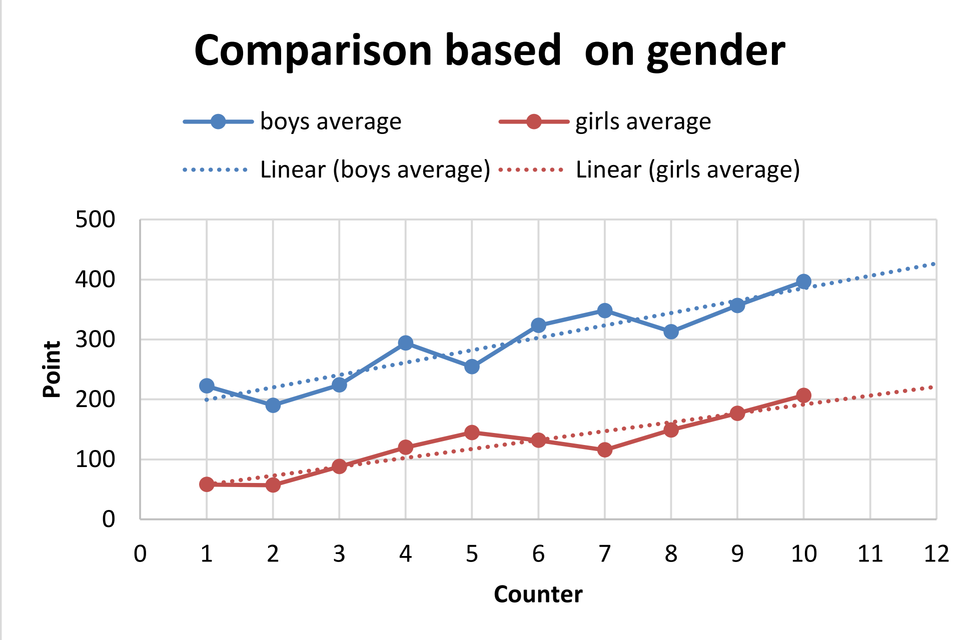

Figure 6. Operation of the autistic children in 10 turns based on their gender.

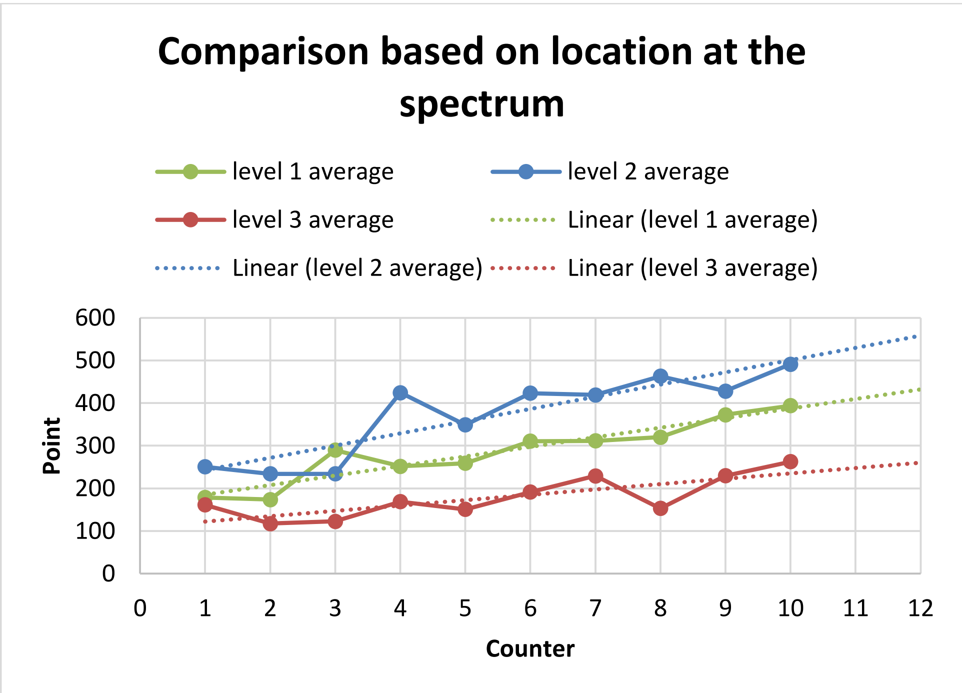

Figure 7. Operation of the autistic children in 10 turns based on their location at autism spectrum disorder.

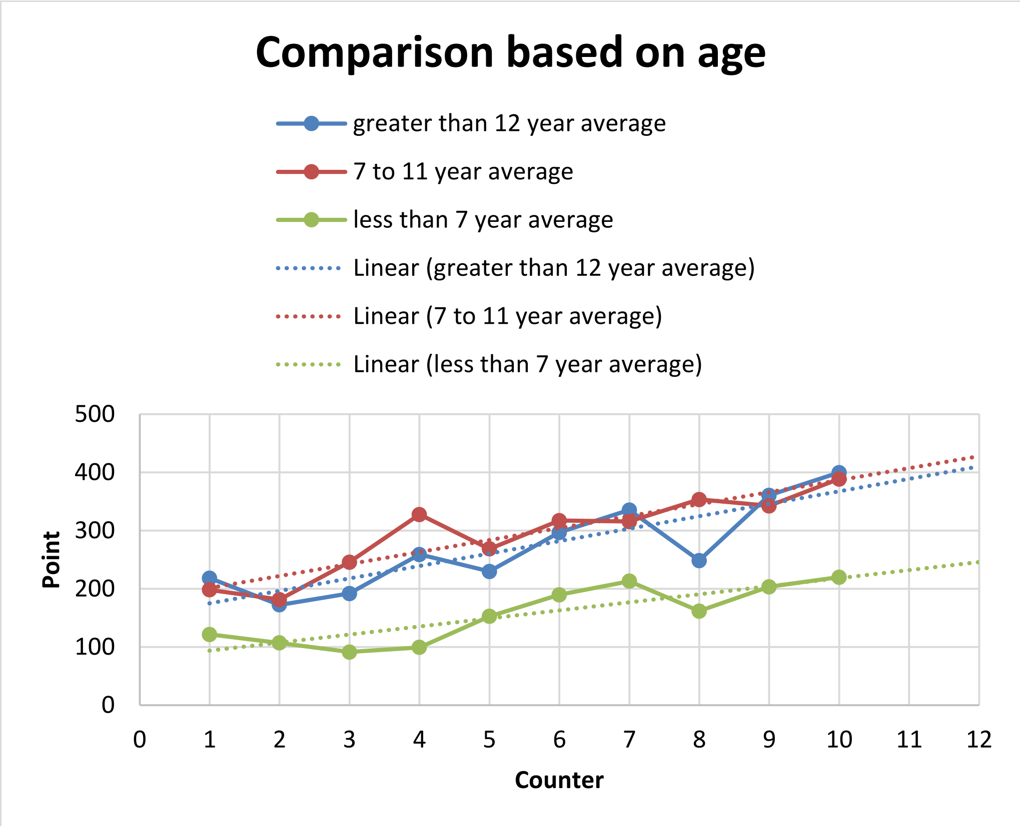

Figure 8. Operation of the autistic children in 10 turns based on their age.

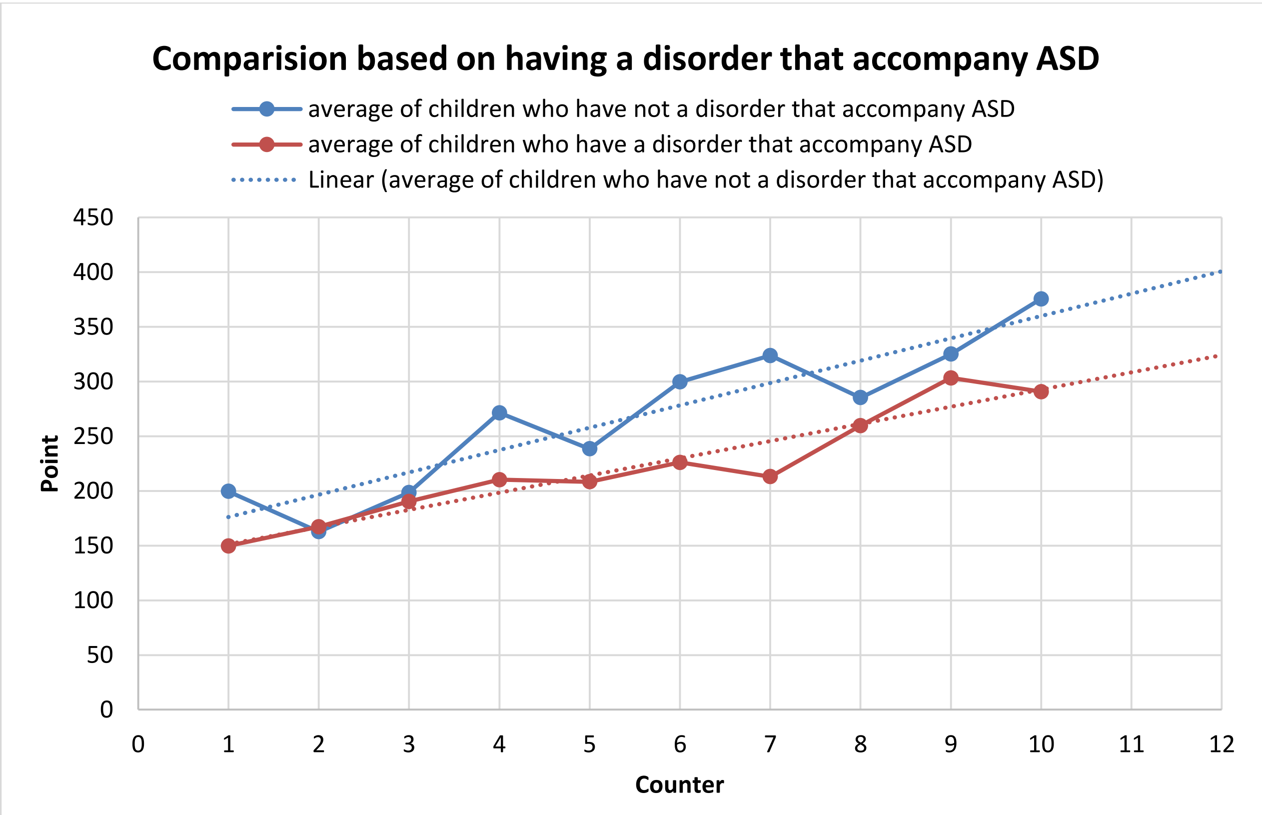

Figure 9. Operation of the autistic children in 10 turns based on having or not having another disorder that accompanies ASD.

Also some of the children who were present at the time were completely reluctant to participate or were not permitted by the staff to participate as it was dangerous for them due to their situation at the time. Because of these reasons, we had not any option to maintain the symmetry and to repeat the game to have better and more precise results. About the control group, we had access to a class of boys but only some girls due to the limitations we had in a girl's primary school. Thus we decided to have symmetry between the control group and the autistic group in aspects of number and gender.

One of the most substantial advantages of this research work is designing and producing a more progressivist "serious game" than the related research's games. The more appealing environment and interface of this game are also effective in increasing children's desire for playing and learning via play. Having dynamic intelligence and through that, the game itself simulates the dynamics of the real world. This feature might help children with ASD to encounter social activities. Also using VR or AR technology might be noticeable and functioning. Although it would be hard to lure an autistic child to use the equipment needed for playing a VR-based game, if this is possible, it would be a gate to a three-dimensional adaptive game that would nearly simulate the actual world.

Also a combination of AR technology, hardware systems, and toys might be advantageous. Already it is proposed that AR is helpful for autistic children's learning, primarily autonomously learning. Mixing the learning aspects of an AR app and a serious adaptive game would be fascinating. This mixture would give a new level of perception and treatment to the game proposed in this paper.

Developing an adaptive AR game is more feasible than a VR game as it is more comfortable for an autistic child to play with a smartphone or tablet instead of VR gadgets and eye monitors.

A technical defect of the game is the short total time of the game. The intelligent agent would not train enough and cannot make a comprehensive effect in a short time. It is notable to mention that the game becomes more boring for children for a longer time, which is also a big issue. It is essential to find the most balanced timing of the gameplay.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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طراحی یک بازی جدی برای کمک به کودکان اوتیستیک با استفاده از یادگیری تقویتی و منطق فازی

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چکیده:

اختلال طیف اوتیسم (ASD) مجموعه ای از ویژگی‌های ناپایدار است. برخی از این ویژگی‌ها، ناهنجاری در ارتباطات اجتماعی متقابل و نـاتوانی در درک الگوهای ارتباطی و علایق و اقدامات می‌باشند. بازی‌های رایانه‌ای تأثیرات مثبتی بر کودکان مبتلا به اوتیسم دارند. بازی‌های جـدی بـه طـور گسـترده‌ای برای افزایش توانایی برقراری ارتباط با افراد دیگر در این کودکان استفاده شده‌اند. در این مقاله، ما یک بـازی جـدی تطبیقـی بـرای ارزیـابی مهارت‌هـای اجتماعی کودکان اوتیستیک پیشنهاد می‌کنیم. بازی جدی پیشنهادی از یک فرآیند یادگیری تقـویتی بـرای ارزیـابی رتبه‌بنـدی‌های بازیکنـان اسـتفاده می‌کند. همچنین در این بازی از منطق فازی برای تخمین مهارت‌های ارتباطی کودکان اوتیستیک استفاده می‌کند. این بـازی خـود را بـا سـطح کـودک مبتلا به اوتیسم تطبیق می‌دهد. برای این انطباق، از یک عامل هوشمند برای تنظیم چالش‌ها در زمان بازی کردن، استفاده می‌شود. برای ارزیـابی پویـای مهارت‌های ارتباطی این کودکان، چالش‌های بازی بر اساس رشد مهارت‌های کودک در طول زمان بازی سخت‌تر می‌شوند. مـا همچنـین از منطـق فـازی برای تخمین دوره‌ای توانایی‌های بازی کودک استفاده می‌کنیم. ۱۵ کودک مبتلا به اوتیسم برای ارزیابی بازی جـدی ارائـه شـده در آزمـایش‌هـا شـرکت کردند. نتایج تجربی نشان می‌دهد که روش پیشنهادی در مهارت‌های ارتباطی کودکان اوتیستیک مؤثر است.

کلمات کلیدی: بازی انطباق پذیر، یادگیری تقویتی، اوتیسم، بازی جدی.