

# The Development of Game to Develop the Cognitive Skill for Autistic Children via Virtual Reality

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## Abstract

This research proposes a virtual reality game to develop the cognitive skill for autistic children and presents satisfaction assessment to our proposed game. The game aims to develop cognitive skills, especially, in the case of developing listening skills and recognition skills (memory) of autistic children during the age of 8-11 years with three sequential parts. Part I is a developmental training on listening and memorization about traffic rules, animals, and virtual environments. The purpose of virtual reality is to add a feeling of realistic that appeals to the user. Part II is a game to test cognitive skills and to learn the rule based on game. Lastly, Part III is a report generated for parents, caregivers, and doctors, so that they have information for the traceable intelligence of cognitive development of children found in Parts I and II. There are 15 sample subjects (5 autistic children and 10 caregivers). The instruments used in this study were our proposed game and questionnaires. Mean and standard deviation are used to analyze data. The results showed that the overall satisfaction of our proposed game, which assessed by autistic children and caregivers was good at the level ( $\bar{x} = 4.05$ , S.D. = 0.69 and  $\bar{x} = 3.99$ , S.D. = 0.67, respectively).

such as communication and socialization [2]. Autistic children are differed from common kids, especially, in the aspects of communication skills and behavior [3], [4]. Most of the problems of autistic children are problems with “behavior, emotions, society, and complex cognitive learning such as problem-solving, memory, and logical thinking skill” [5]. So, the general treatment is “behavior adjustment and skills teaching” [6].

“Traditional teaching approaches are face-to-face instructions from the teacher and parent”. However, this method is ineffectively for autistic children because it is not interesting and exciting for learning of children [7]. Thus, virtual reality (VR) is one of the most interesting technology for developmental training of autistic children because VR enables content attractiveness and adds a sense of reality [8]. Especially, in-game, the virtual reality can stimulate perception and learning in children [9], [10], [11]. There are numerous researches, which use VR for the developmental training of autistic children with various activities such as simulation of car driving, simulation of toilet using, and simulation of playing music [12-16]. However, most of the researches focus on developmental training of social skills and behavior skills, which may be not be the first priority for autistic children. In the initial stage, autistic children should receive developmental training of major knowledge-based on cognitive skills such as listening skills and recognition skills (memory) before other skills for ease of living, because autistic children usually have “impairment in correlative thinking, decision making, prioritizing, and speech repetition” [17]. Thus, the tool for support learning of autistic children

**Keywords:** Developmental Training Game, Autistic Children, Virtual Reality, Cognitive Development, Smartphone.

## 1. Introduction

Based on the latest study in Thailand, 372,000 out of 62 million Thai population (equal to 0.6%) have autism [1]. Autism is a neurological disorder, which affects daily activity

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should be interesting and can enhance the learning of autistic children to develop cognitive skills.

This paper proposes a game of developmental cognitive skill for autistic children using virtual reality and presents satisfaction assessment to the game. The system is divided into three parts: developmental training for correlative thinking, a game for a decision making, and reported support. The system focuses on the development of listening skills and recognition skills of autistic children during the age of 8-11 years. VR can encourage the learning of autistic children because of realistic and attractive. The game aims to teach the rules. The score is reported to the parent and caregivers so that they have information on development of autistic children. Then, we request satisfaction assessment from the user to improve the quality's game.

This paper is organized as follows: Section 2 presents related researches; Section 3 presents the conceptual framework for research; Section 4 describes the research methodology of our proposed system; Section 5 presents the results; finally, Section 6 presents the conclusion and future work.

## 2. Related Researches

The systems have been developed to assist developmental training of autistic children in various skills such as "social skills, communication skills, and cognitive skills using a computer base" [18], [19], [20]. For the view of developmental training, there are various techniques such as "games, virtual reality, robot, and augmented reality" [21], [22], [23]. Vallefouco, et al. [24] developed a game for autism children. The game aims to develop the learning skill of autism children. Bernardes, et al. [25] and Simões, et al. [26] developed a game for autism children as same as Vallefouco, et al. [24]. The game is designed to support play via virtual reality. The game can improve the learning of autism children to use public transportation. Pongpinigpinyo [27] proposed a game to develop the mathematical skill of autistic children using augmented reality. This game aims to practice purchase items in the store. The result shows that the overall satisfaction of

the proposed game was good at the level ( $\bar{x} = 4.40$ ). Hosseini and Foutohi-Ghazvini [28] presented an augmented reality game using a mobile phone. The game focuses on development of communication skills.

Moreover, Mozafari and Shariati [29] developed a robot for autism children. The robot can communicate and can reach nature of autism children. The result shows a robot can help develop the skills for autistic children. Kaewkamnerpong [30] developed a robot to develop the social skills of autistic children. The robot is used to learn the emotions of autistic children using sound and visual effect.

In addition, Strickland [31] presented an application to develop the skill of autistic children using virtual reality (VR). Zhang, et al. [12] proposed a system to develop the driving ability of autistic subject using VR. The system detects cognitive learning from eye gaze data. Classification methods are used to detect cognitive learning such as "Naïve Bayes, SVM, Logistic Regression, K-Nearest Neighbor, Neural Network, and Decision Tree". The result shows that K-Nearest Neighbor can detect cognitive learning with 78.38% accuracy. Ramachandiran et al. [13] proposed a surrounding setting for learning of autistic children using VR. The study shows that the most important skill for the learning of autism children is using the toilet. Feng and Cai [14] developed a virtual reality game for autism children using a gazing eye in responding to the game. The system can improve communication skills and social skills. Shahab, et al. [15] and Taheri, et al. [16] developed applications to learn music for autism children using virtual reality system and robot. The result shows that the application can help develop the skills of children. In addition, autistic children enjoy using headset. Josman et al. [32] proposed a virtual reality game to develop street-crossing skills of autistic children. The result shows that the system can help improve crossing skills of autistic children. Rosenfield et al. [33] developed a virtual reality game to develop communication skills of autistic children based on Bob's Fish Shop case study. The game can enhance communication and socialization.

### 3. Conceptual Framework for Research

From the literature review, this research's aim to develop games that can develop cognitive skills (listening skills and recognition skills) for autistic children via VR. Conceptual framework for research is defined as shown in Figure 1.

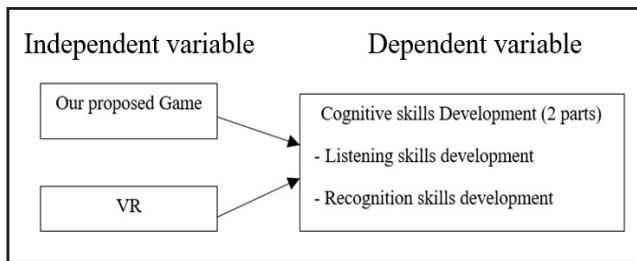


Figure 1. Conceptual framework for research.

From Figure 1, conceptual framework for research consists of 2 variables: independent variable (our proposed game and VR) and dependent variable (cognitive skills development).

### 4. Research Methodology

In this section, we describe development process of our proposed game and presents satisfaction assessment to game as shown in Figure 2.

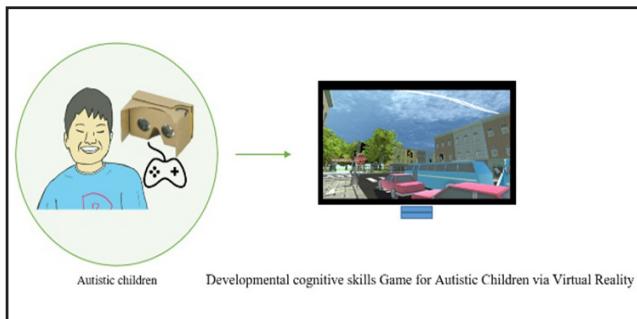


Figure 2. Overview of our proposed game.

From Figure 2, the process of game development and satisfaction assessment method of user to our proposed game are described in detail, next.

#### 4.1 Developing a Game to Develop Cognitive Skills for Autistic Children Via Virtual Reality

The development of game is divided into 6 processes as follow as:

##### 4.1.1 Study and investigate theory

We have studied theory on the development of game via virtual reality and have inquired computer game design experts.

##### 4.1.2 Inquire needs

We have inquired needs about the pattern and elements of the game from autistic children, caregivers, and experts in autism to help design the game.

##### 4.1.3 Analyze and design game

Relying on the needs of the user, analysis and system design are divided into 3 parts: developmental training part, game part, and report part as shown in Figure 3.

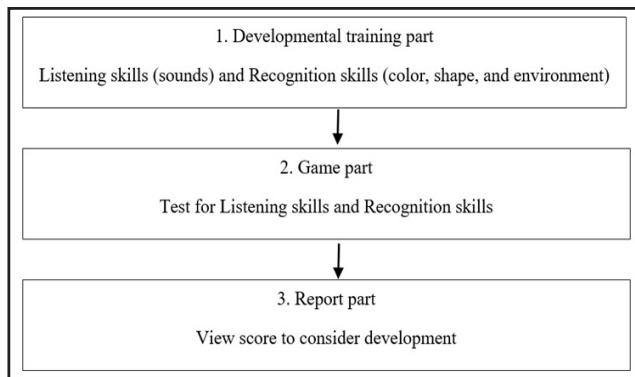


Figure 3. Work flow of our proposed game.

From Figure 3, workflow of our proposed game consists of components as follow as.

##### 1) Developmental training part

From the study of the problem of autistic children, “they have various learning disorders as mentioned in the introduction, especially communication [34]. So, speaking, listening, and facial expressions are important” [35]. The method helps to solve communication. It should started with the development of cognitive skills such as listening and recognition skills. Nevertheless, each child may have different levels of cognitive such as intelligence quotient and environmental factors. “Thus, teaching method for learning is divided into 3 parts: 1) interesting activities and suitable for autistic children 2) environment and 3) game” [42]. From the above reason and collaborated design with experts in autistic children, this research uses the traffic rules and the zoo via VR because children are interested in environmental survey and the context that is easy and necessary to develop children’s learning. The children can learn colors, shapes, sound of animal, and traffic rules in the virtual environments.

The design of the developmental training is aimed to encourage the learning skills of the children which is divided into 2 parts: encouraging recognition skills and encouraging listening skills.

For encouraging recognition skills, we focus on the traffic rules because children can perceive the traffic rules for their daily life such as crossing the street. In the zoo, we focus on the ability of the children to be able to distinguish colors, names, shapes, and sounds of animal.

For encouraging listening skills, we design the developmental training for learning the sound and speech of animal.

## 2) Game Part

After autistic children learn listening skills and recognition skills from developmental training part, we have designed games to test their skills in listening and recognition.

The style of game is listening and complying to the instruction using the same environment as training part. So, autistic children can learn the rules and review their memory. For example, the problem is finding a pig. Children must walk to find answers along the path. If the selected answer is incorrect, they have to go back to choose a new answer.

### 3) Report

Once game is finished, the score will be appeared on the total score screen to parents, caregivers, and doctors, so that they have the record of the cognitive development of children.

#### 4.1.4 Write the storyboard of the system

Once, the system is analyzed and designed as explained in 4.1.3, we have written the storyboard of the system, which is divided into 2 parts: development training part and game part as shown in Figure 4.

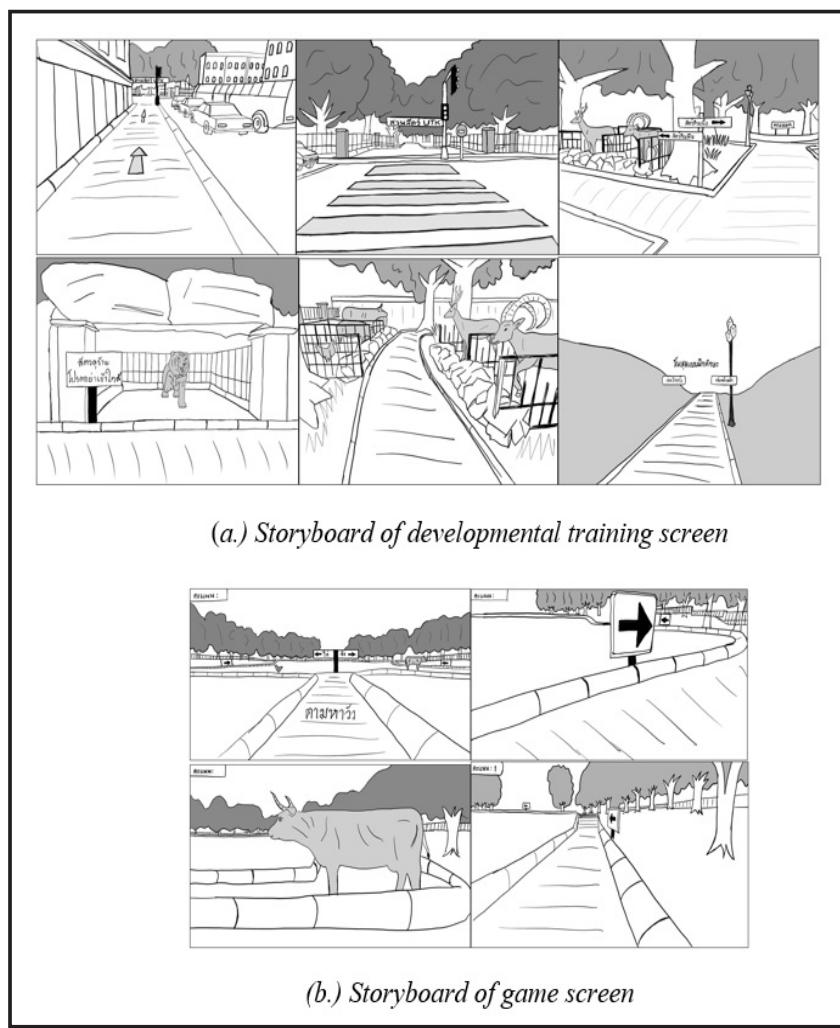


Figure 4. Storyboard of our proposed system.

Figure 4(a) shows the storyboard of development training part, which consists of 5 scenes: The start scene is walkway. Next, it is a scene of the traffic lights to learn the rules for crossing the street. When children enter the zoo, there are 2 zones: herbivores zone and carnivores zone. The children can go to the cage and the sound of animal will be loud, together with the speech to tell the type of animal. If animal was a ferocious animal, it has a warning label. In addition, children can walk around the zoo area to learn. Finally, children can choose whether they practice their skills again or return to the main screen. Figure 4(b) shows the storyboard of the game part, which consists of 3 scenes: the start scene is complying to the instruction for finding animal by walking along the path. When they found the answer, they will get the point. If the answer is incorrect, they can walk back and choose a new answer. Finally, the children must follow the instructions until the end of the game.

#### 4.1.5 Develop a game

Once, storyboard of the system is designed, we will be developed. Unity program [36] is used to develop 3D games for realistic and interesting appearance of the game. Then, Trinus virtual reality [37] is used to display the result on the computer and smartphone. Java [38] is used to control the game.

#### 4.1.6 Find efficiency of system by experts using questionnaire.

Before user assessed satisfaction, we performed pre-survey by experts. The game is tested an efficiency by experts and sample subjects. There are 3 persons namely information technology expert, computer game design expert, and content expert. From the test, the overall average of the game was good at the level ( $\bar{x} = 3.93$ , S.D. = 0.75). In addition, the game is tested by autistic children.

### 4.2 Satisfaction Assessment Method to Our Proposed Game

Once a system is developed, satisfaction assessment from users will be preceded. Each component of satisfaction assessment is described in detail, next.

#### 4.2.1 Research Hypothesis

The satisfaction of autistic children and caregivers in our proposed game to improve cognitive skills at a good level.

#### 4.2.2 Research Instrument

There are 2 research instruments (satisfaction assessment questionnaire of autistic children and satisfaction assessment questionnaire of caregiver) to game. This questionnaire is a 5 rating scale [39], which consists of very good, good, moderate, fair, and updated. We collect data using questionnaires. Then, the data was analyzed using mean and standard deviation.

#### 4.2.3 Design satisfaction assessment questionnaire for autistic children and caregiver

For satisfaction assessment questionnaire of autistic children to game, this questionnaire consists of five parts in 12 question numbers: 1) content 2) encouraged listening skills 3) encouraged recognition skills 4) GUI design and 5) suitability.

For satisfaction assessment questionnaire of caregiver to game, there are 5 parts (13 question numbers) like previous questionnaire.

The questionnaires are verified consistency between satisfaction questionnaires and content by 3 experts. The result of the Index of Item (IOC) [40], [41] – Objective Congruence evaluation found that the consistency index is between 0.67-1.00. So, this questionnaire can be used.

## 5. Result

In this section, we explain sample subject, data analyzing, and research results.

### 5.1 Sample Subject

Research sample subjects were caregivers (10 subjects) and autistic children during the age of 8-11 years (5 subjects) by Judgement sampling [42]. The characteristic and level of learnability skills of autistic children in our experiment are abnormal recognition and delayed speech, especially, delayed learning and often repeated speech.

For experimental setup, autistic children tested the system and we have slowly described and repeated the instruction during our experiment.

For answering the questionnaire, we read and explained each question to autistic children as shown in Figure 5.



Figure 5. Test of our proposed game.

## 5.2 Analyzing

Once the information has been collected, we have been verified the correctness and completeness of questionnaire. Then, the data was analyzed using mean and standard deviation and average score criteria are used to interpret [43].

## 5.3 Research Result

To gain an insightful research result, we assessed satisfaction of user as follow as.

5.3.1 The results of the satisfaction questionnaire of autistic children to system

Satisfaction assessment results from autistic children (5 subjects) are shown in Table 1.

From Table 1, the overall satisfaction of autistic children to our proposed game was good at the level ( $\bar{x} = 4.05$ ,  $S.D. = 0.69$ ), which conforms to our hypothesis. The results found that satisfaction was very good at the level such as the content is easy to understand, the sound is clear

**Table 1.** Satisfaction assessment results of Autistic children.

Items	Satisfaction		
	$\bar{x}$	S.D.	Interpretation
1. Content			
1.1 The content is easy to understand	4.40	0.49	very good
1.2. The content is interesting	3.80	0.40	good
2. Encouraged listening skills			
2.1 The sound is clear and uses language that is easy to understand.	4.40	0.49	very good
2.2 the system can help to learn listening skills and separate sound	4.40	0.49	very good
2.3 The system can help to understand meaning of activity learning	3.80	0.40	good
3. Encouraged recognition skills			
3.1 Images or symbols can convey meaning clearly.	4.80	0.40	very good
3.2 Images or symbols are easy to remember	4.40	0.49	very good
3.3 Images or symbols can help to remember	4.40	0.49	very good
4. GUI design			
4.1 The scene is realistic	4.00	0.63	good
4.2 Colors and fonts are clear.	4.40	0.49	very good
5. Suitability			
5.1 The duration of development training skills and playing the game is appropriate.	3.40	0.49	moderate
5.2 The material of the VR goggles is suitable for users.	2.20	0.75	fair

and uses language that is easy to understand, the system can help to learn listening skills and separate sound, images or symbols are easy to remember, images or symbols can help to remember, and colors and fonts are clear with  $\bar{x} = 4.40$  and  $S.D. = 0.49$  and images or symbols can convey meaning clearly ( $\bar{x} = 4.80$ ,  $S.D. = 0.40$ ). Satisfaction was good at the level such as the content is interesting and the system can help to understand meaning of activity learning ( $\bar{x} = 3.80$ ,  $S.D. = 0.40$ ) and the scene is realistic ( $\bar{x} = 4.00$ ,  $S.D. = 0.63$ ). Satisfaction was moderate at the level that is the duration of development training skills and playing the game is appropriate ( $\bar{x} = 3.40$ ,  $S.D. = 0.49$ ). Finally, satisfaction was fair at the level of the VR goggles material which is suitable for users ( $\bar{x} = 2.20$ ,  $S.D. = 0.75$ ). The reason the user is not satisfied with the material of the VR goggles because it is the prototype phase. Therefore, it is unable to interact using remote control, unlike commercial products. In addition, the user would like

to add more types of animals and plants.

5.3.2 The results of the satisfaction questionnaire of caregiver to system

Satisfaction assessment results from caregivers (10 subjects) are shown in Table 2.

**Table 2.** Satisfaction assessment results of Caregiver.

Items	Satisfaction		
	$\bar{x}$	S.D.	Interpretation
1. Content			
1.1 The content is interesting and appropriate for autistic children	3.90	0.54	good
1.2 The content is consistent	4.70	0.46	very good
2. Encouraged listening skills			
2.1 The system uses language that is easy for autistic children to understand	3.90	0.30	good
2.2 The sound is clear	4.70	0.46	very good
2.3 Repeated speech can stimulate a child's listening	4.50	0.50	very good
3. Encouraged recognition skills			
3.1 Images or symbols can stimulate a child's recognition	4.60	0.49	very good
3.2 Images or symbols can convey meaning clearly	4.40	0.49	very good
4. GUI design			
4.1 The style of the game, color, and size of font are suitable for autistic children	4.20	0.40	good
4.2 The scene is realistic	4.00	0.45	good
4.3 Lay out is appropriate	4.10	0.54	good
5. Suitability			
5.1 The speed and response times of the system are appropriate	3.30	0.90	moderate
5.2 The duration of development training skills and playing the game is appropriate	3.40	0.75	moderate
5.3 The material of the VR goggles is suitable for users.	2.20	0.87	fair

From Table 2, the overall satisfaction of caregivers to our proposed game was good at the level ( $\bar{x} = 3.99$ , S.D. = 0.67), which conforms to our hypothesis. The result shows that satisfaction was very good at levels such as the content is consistent and the sound is clear with  $\bar{x} = 4.70$ , S.D. = 0.46, repeated speech can stimulate a child's listening ( $\bar{x} = 4.50$ , S.D. = 0.50), images or symbols can stimulate a child's recognition ( $\bar{x} = 4.60$ , S.D. = 0.49), and images or symbols can convey meaning clearly ( $\bar{x} = 4.40$ , S.D. = 0.49). Satisfaction was good at the level such as the content is

interesting and appropriate for autistic children ( $\bar{x} = 3.90$ , S.D. = 0.54). The system uses language that is easy for autistic children to understand ( $\bar{x} = 3.90$ , S.D. = 0.30), the style of the game, color, and size of font are suitable for autistic children ( $\bar{x} = 4.20$ , S.D. = 0.40), the scene is realistic ( $\bar{x} = 4.00$ , S.D. = 0.45), and layout is appropriate ( $\bar{x} = 4.10$ , S.D. = 0.54). Satisfaction was moderate at the level such as the speed and response times of the system are appropriate ( $\bar{x} = 3.30$ , S.D. = 0.49) and the duration of development training skills and playing the game is appropriate ( $\bar{x} = 3.40$ , S.D. = 0.49). Also, caregivers have satisfaction with the material of the VR goggles at fair level ( $\bar{x} = 2.20$ , S.D. = 0.87). Moreover, caregivers suggest that our proposed system is beneficial in the interaction between caregivers and autistic children to joint activities and increase the child's concentration in focus learning because they are interested in the content.

Furthermore, Figure 6 shows the screen of proposed system. The display is divided into 3 parts: developmental training part, game part, and report.

Figure 6(a) shows developmental training screen for listening skills and recognition skills of autistic children. For example, autistic children can learn to cross the street, the traffic lights, turn left, turn right, color, name, shape, and sound of animals. Figure 6(b) shows game screen based on conditions that want children to learn for repeated memory, rule, and communication. Figure 6(c) shows total score screen. A report generated for parents, caregivers, and doctors, so that they have information for the traceable intelligence of cognitive development of children found in developmental training part and game part.

In addition, our proposed game conforms to Suttijak et al. [18]. This study develops a game based on the computer to practice the separation skill of color, size, and shape. This game focuses on the learning of cognitive skills and recognition skills. Autistic children have to use the skills of using the computer. Nevertheless, our proposed game aims to realistic and the attractive of the game to encourage the learning of autistic children.

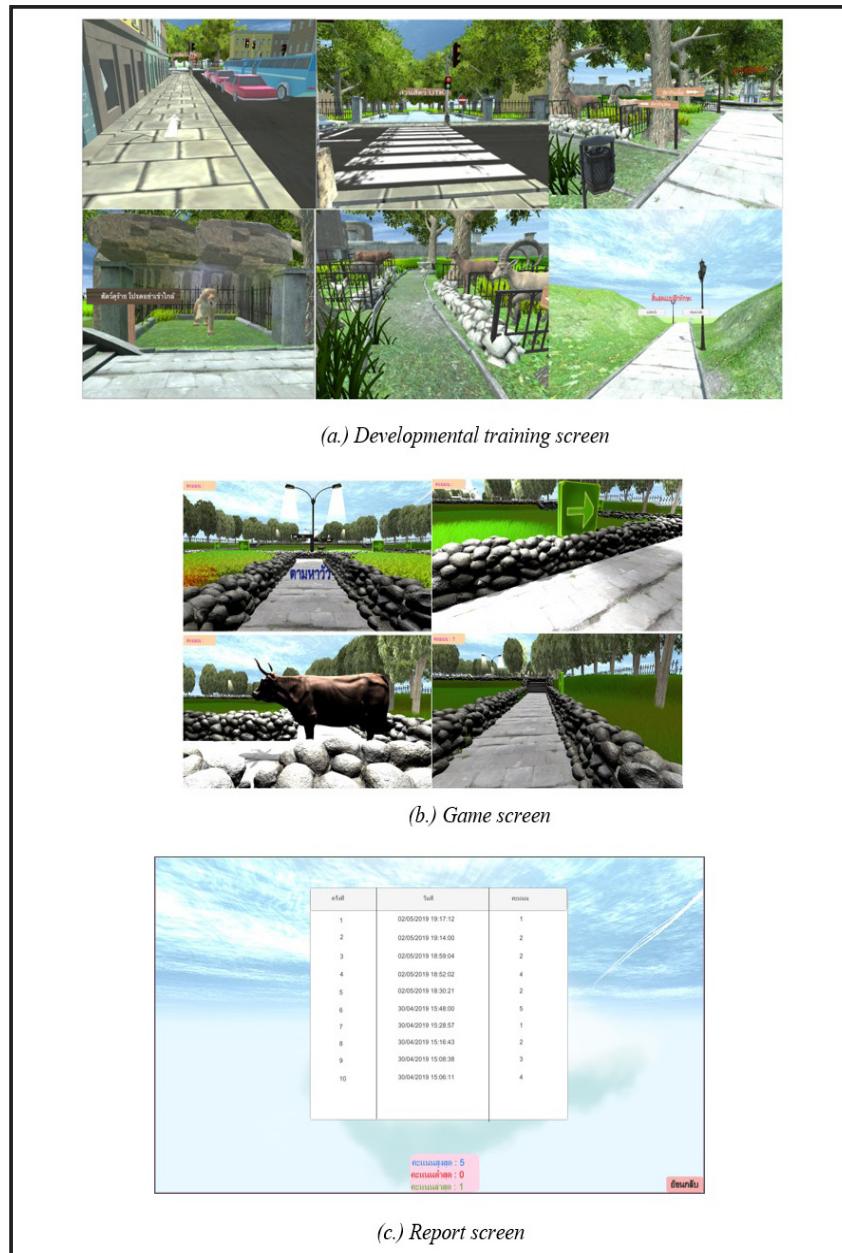


Figure 6. Screen of a developmental cognitive skill game.

## 6. Conclusions and Future Work

In this paper, we proposed a game to develop the cognitive skills for autistic children using virtual reality and presents satisfaction assessment of the game. The game aims to develop listening skills and recognition skills of autistic children during the age of 8-11 years. The game is divided into three parts: developmental training, a game, and reported support for a parent, caregivers, and doctors, so that they have information for the traceable intelligence of cognitive development of children. The results showed that the overall

satisfaction of our proposed game, which assessed by autistic children and caregivers was good at the level ( $\bar{x} = 4.05$ , S.D. = 0.69 and  $\bar{x} = 3.99$ , S.D. = 0.67, respectively).

For future work, we plan to change the material of the VR goggles and add more types of animals and plants. In addition we will extend the system by integrating other developmental training such as social skills and behavior skills to improve learning of autistic children. In addition, we plan to deploy our prototype system in real use.

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