A New Evaluation Technique Through Serious Games for Children with ASD

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Abstract—Assessment at preschool age plays a crucial role in the process of learning especially for children with autism spectrum disorder (ASD), whom encounter communication difficulties as exchanging thoughts or information by speech, writing or nonverbal expression. Therefore, a well-designed assessment method is necessary in order to guide learning and serve as a powerful tool to reinforce children's motivation to learn. Information about what a child with ASD knows, understands and is able to do is used by tutors to adjust their teaching strategies. All assessment methods have different purposes before, during or after instruction. Besides, formative assessment is the most recommended type that helps improving children's learning and it takes place during the learning process. Also, serious games provide a context for assessing a broader range of skills and constructs compared to traditional assessment approaches. In this article, we propose a new technique for evaluating the degree of concept's assimilation of children with ASD through serious games. It allows identifying concepts that children are struggling to understand and skills they are having difficulty acquiring.

Keywords—Evaluation, ASD, Serious Games, Education, Technique

1 Introduction

Autism Spectrum Disorder (ASD) is a complex disorder characterized by social and communication difficulties and by restricted or repetitive behaviors or interests [1]. These difficulties considerably affect the skills necessary for learning, which disrupts the acquisition, understanding, use and processing of verbal or non-verbal information.

It is not only about the acquisition of basic skills such as reading, writing and / or mathematics, but even higher skills such as organization, time planning, abstract reasoning, long-term memory or short term and attention.

Children with ASD have trouble interpreting social cues which influence their ability to adapt their behaviors or even exhibit inappropriate social behaviors due to abnormal social development. It is an evolutionary process by which individuals adapt their learning skills and behavior to the context [2].

Assessment is a process that involves gathering, analyzing and interpreting learning information in order to make a judgment on the child's situation and to make a decision on his or her further development. Assessment generally has two functions, a social and

an educational function. The forms of evaluation are classified into several categories according to the assigned function (summative, formative and certification, etc.) [3-4]. The National Foundation for Educational Research in the United Kingdom [5] classifies the types of assessment according to the learning objective, it distinguishes three classes:

- Assessment for learning
- Assessment as learning
- Assessment of learning

In addition, Roediger [6] defines evaluation as "a task of mobilizing and using knowledge, so it has the effect of reinforcing learning". To evaluate [7] is to situate an act in relation to a reference. However, evaluation as a measuring instrument consists in assigning a value to this difference between act and reference. It is also an essential tool for the design, implementation and regulation of a teaching-learning situation. However, children with ASD struggle in self-expression, so assessing what a child with ASD has learned seems to be a complicated issue. Micah Mazurek [8] assumes that young people with ASD are attracted to video games because they can be rewarded without having to first socialize or communicate. Therefore, using the potential of serious games in such situations provides acquiring implicitly their understanding.

This article presents a new evaluation technique that allows assessing an autistic child's understanding through serious games. In this perspective, the article first presents related work to the evaluation topic; it establishes the importance of evaluation in the learning process. Then, it sets out the potential of serious game as an assessment tool especially for children with ASD. Subsequently, the second part is devoted to the proposed technique. The fourth section exhibits a practical example of the proposed technique. Finally, it presents a discussion of the strengths and limitations of the proposed technique.

2 Literature Review

Evaluation is an integral part of the learning process. Traditionally, assessment of learning has focused only on factual content, and progress has been assessed using methods such as written exams. However, in order to assess learning in areas such as creativity and critical thinking, it is necessary to use non-traditional methods. Increasingly, tutors will use strategies such as observation, interview, written and oral work and performance evaluation to gather knowledge in order to measure the child's progress.

Hence, the immersive nature of SGs allows children to make decisions in a context, or even find themselves in the shoes of a character. As the game progresses, the child learns to fit to these needs and practices in different types of situations.

The term Serious Games was outlined in the founding work of Clark Abt [9]. He defines it as follows: "*these games have an explicit and carefully designed educational purpose and are not intended to be primarily played for fun*".

Serious games are an increasingly interwoven practice in several fields and are designed for various purposes, such as: entertainment, learning, therapy or social control [10]. When playing, the child expresses himself indirectly through his choices, his reactions and his decisions: *"Play is the highest development of childhood, because it alone is the free expression of what is in his soul. ... Children's play is not a simple sport. It is full of meaning and import"* [11].

Several studies have proved the efficiency of using Serious Games as a tool to encourage the development of communication, learning process and social behavior of people with ASD, in addition to traditional therapeutic approaches. From Urturi et al. [12] have implemented an Android application to educate first aid for people with ASD and have proven that people with autism feel more relaxed by practicing the activities as educational games. Bernardes et al. [13] published a study on an SG aimed at training people with ASD to use the bus, the publication demonstrates the power of games and virtual reality in improving the capacities of people with ASD. ISpectrum [14] is another serious software developed in the training field. It aims to enhance work capacities and skills.

In this respect, the ludo-pedagogy not only promotes active learning as described by Matsushita [15], but also the evaluation procedure. Through SGs, tutors could effectively measure the comprehension level of children with ASD in order to guide the content of the educational scenario.

El Alami et al. [16 - 17] argue that the precise determination of student learning has always been an important point for several objectives, such as the choice of corrective tactics to fix learning errors and improve the effectiveness of learning systems. Roediger and Karpicke [18] argue that assessment is a powerful means to improve learning. Indeed, monitoring autistic children's learning and obtaining regular feedback is a beneficial practice. Thus, the major advantage of the proposed technique is to provide early and targeted learning aids.

Most research work on evaluating children with ASD concern diagnostic. They differ according to the age and pathology of the target population, and are generally based on questionnaires, direct observation or interviews [19-24]. For instance, Millar et al. [25] present a serious game serving as a screening tool intended for children of school age, its objective is to diagnose if the child has an ASD or another neurodevelopmental disorder.

In addition, some projects are intended for families of children with ASD [26], health care providers [27], or tutors [28] in order to allow their awareness and attitudes towards ASD for but sensitization. Nevertheless, no project concerns using serious games as an evaluation tool in order to monitor the progress of the autistic children's learning.

The proposed technique allows to measure the children's action in a virtual context. It requires a fast analysis of sensorimotor information in order to reveal hidden states, including mental states (such as beliefs, intentions). These games are designed in accordance with the axes of KASP methodology [29] which ensures better modeling of the game scenes taking into account the cognitive, emotional and sensory aspects of the child. Based on child's knowledge models, derived from DIAUTIS platform [30], it allows an adapted game scene suitable to each children's needs. DIAUTIS offers a battery of tests of different categories, it aims to identify the category of autism spectrum

disorder as well as its intensity through the ability to learn from experience. It is a multi-agent system with the functionality of cognitive, fuzzy and affective computing.

3 Proposed Technique

Assessment plays an essential role in providing useful information to guide learning and to adapt the learning mode to autistic children's specificities. The main goal of the technique is to measure the degree of assimilation of a concept by a child with ASD in order to be able to assess his learning progress, this evaluation will allow children, tutors and parents, as well as educational community at large, to be informed about learning outcomes in order to highlight successes, plan interventions and continue to promote learning.

Evaluating an autistic child's understanding in relation to his environment is a complex practice. For this reason, the authors propose to use serious games as an intermediary to take advantage of the motivation and commitment of children in order to measure the degree of assimilation of the concepts exposed in scenes of the game.

A game is characterized by an intention, a genre, a main concept, conditions of victory and defeat which are the objectives of the scenes composing the game, and a narration. The harmony between the objective and the concepts making up the scenes must first ensure the effectiveness of the scenario in order to recount a coherent and interesting story.

In order to measure the degree of assimilation of a concept by a child with ASD, it is necessary to take into account the sub-concepts constructing the main concept (objective of the game). Mathematically, it is referred to compare the sub-concept's weights of the child to those of the expert in order to identify actions that caused a significant degradation of the sub-concepts' weights. The actions made by the child influence the weights of the sub-concepts which generates a new vector consisting of new values of the sub-concept's weights.

Therefore, the expert is led to propose a serious game allowing the evaluation of a concept in children with ASD. This game is made up of several scenes:

$$Game = \{S_\alpha; S_\beta; S_\gamma; \cdots\} \text{ such that } S_i : \text{a game scene}$$

The main objective of the game is identical to the main concept that the expert intends to evaluate. Each game scene is formed of several objects, where each object represents a sub-concept. The objects interact with each other following the actions made by the child:

$$S_\gamma = (C_\gamma, A_\gamma) \ such \ that \ \begin{cases} C_\gamma = \{C_{\gamma_1}; C_{\gamma_2}; C_{\gamma_3}; \cdots\} : set \ of \ the \ scene's \ concepts \ S_\gamma \\ A_\gamma = \{A_{\gamma_1}; A_{\gamma\alpha_2}; A_{\gamma_3}; \cdots\} : set \ of \ the \ scene's \ actions \ S_\gamma \end{cases}$$

Any action is characterized by a weight, which expresses the influence of the action on the concept. This weight is expressed using the Likert scale [31], which is considered

one of the most reliable tools for measuring perceptions. It is made up of 5 levels (see Table 1):

$$\forall A_{\gamma_i} \implies W_{\gamma_i} \in [1,5]$$

Table 1. Likert scale

1	2	3	4	5
Very wrong action	Wrong action	Acceptable action	Correct action	Very correct action

In addition, any action is defined by:

- **A triggering event**: When an event is received, a transition can be triggered and switch the object to a new state assessment as learning
- **Intensity**: It is a weight that reflects the strength of the emitted action and it is specified by the expert.
- **And a guard condition**: It is evaluated only when the triggering event occurs. If the expression is false, the transition does not trigger, if it is true, the transition triggers and its effects occur.

Moreover, the expert assigns a weight to each concept to describe its importance in relation to the main concept (see Table 2). The weighting varies from scene to scene:

$$\forall C_{\gamma_i} \implies V_{\gamma_i} \in [1,5]$$

Table 2. Expert's weights of concepts

Scene : S_γ				
Concepts	C_{γ_1}	C_{γ_2}	C_{γ_3}	C_{γ_4}	
Weights/Main concept	V_{γ_1}	V_{γ_2}	V_{γ_3}	V_{γ_4}	

The expert first provides a semantic network of the scene (see Fig. 1). It is a model that gathers all the concepts and actions as well as their weights. Each concept is represented by a node, the oriented arc connecting two nodes expresses the influence of the action on the concept of destination. For each concept, the expert must specify at least five actions which reflect the weights on the scale[1,5]. The game scenes are specially designed to assess the autistic child's understanding using the KASP methodology [29]. It is a methodology for designing intelligent games centered on diagnosis, it takes into account the cognitive, emotional and sensory aspects of the child.

After a play session, a semantic sub-network of the child is generated (see Fig. 2). It inherits from the expert's semantic network and only contains the actions made by the child and associated concepts.
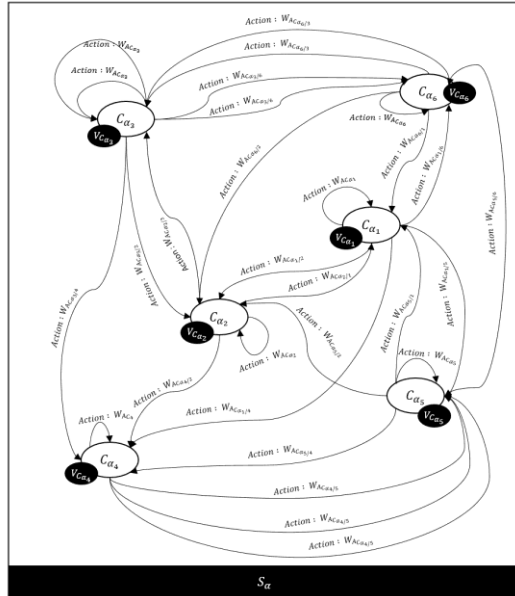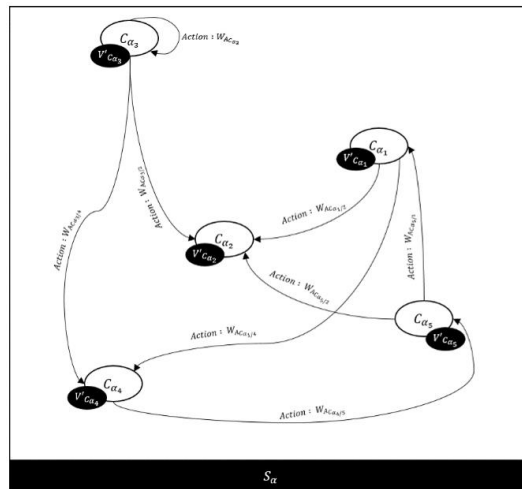
Fig. 1. Expert's semantic network of scene S_α

Fig. 2. Child's semantic network of scene S_α

Thereafter, we generate two matrices from the semantic network, the first matrice matches to the expert (see Fig. 3) and the second is the child's matrice (see Fig. 4). Each matrice consists of n rows and m columns, the columns correspond to the concepts forming the scene and the rows to the actions, the value of the intersection row x column is the weight of the action. Hence, the expert's matrice contains all the varieties of

actions as well as all the concepts, and the one of the children is a sub-matrice of the expert.

	C_{α_1}	C_{α_2}	C_{α_3}	C_{α_4}	C_{α_5}	C_{α_6}
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
...	...	...	...	...	...	...
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$
Action	$W_{Ac_{\alpha_1}}$	$W_{Ac_{\alpha_2}}$	$W_{Ac_{\alpha_3}}$	$W_{Ac_{\alpha_4}}$	$W_{Ac_{\alpha_5}}$	$W_{Ac_{\alpha_6}}$

Fig. 3. Expert's matrice of scene Sα

	C_{α_1}	C_{α_2}	C_{α_3}	C_{α_4}	C_{α_5}
Action	$W_{Ac_{\alpha_1}}$	0	0	0	0
Action	0	$W_{Ac_{\alpha_2}}$	0	0	0
Action	0	$W_{Ac_{\alpha_2}}$	0	0	0
Action	0	$W_{Ac_{\alpha_2}}$	0	0	0
Action	0	0	$W_{Ac_{\alpha_3}}$	0	0
Action	0	0	0	$W_{Ac_{\alpha_4}}$	0
Action	0	0	0	$W_{Ac_{\alpha_4}}$	0
Action	0	0	0	0	$W_{Ac_{\alpha_5}}$

Fig. 4. Child's matrice of scene Sα

Any action applied to a concept entails an influence on the weighting of the concept compared to the main concept V_{γ_i}. In order to calculate this new weighting, we perform a normalization of the Likert scale by transforming the weights [1,5] into values between [0,1] as shown in Table 3 below:

Table 3. Normalized scale

1	2	3	4	5
0,2	0,4	0,6	0,8	1

A new weighting V'_{γ_i} is calculated by applying the following formula (*):

$$V'_{\alpha_i} = W_{\alpha_j} \times W_{\alpha_k} \times W_{\alpha_l} \times \dots \times V_{\alpha_i} = \prod_{j=1}^{n} W_{\alpha_j} \times V_{\alpha_i} \quad such\ that\ \mathbf{n}$$

$$: the\ number\ of\ actions$$

At the end of each played scene, a new weighting of the concepts is calculated to measure the child's understanding of a specific concept through the decisions taken while playing. The interpretation of the result vector explains the way how the child perceives the main concept. Table 4 presents the new weights of concepts related to the main concept:

Table 4. Child's weights of concepts

Scene : S_α					
Concepts	C_{α_1}	C_{α_2}	C_{α_3}	C_{α_4}	C_{α_5}
Weights/Main concept	V'_{α_1}	V'_{α_2}	V'_{α_3}	V'_{α_4}	V'_{α_5}

Table 4 presents the child's vector of the weights of the concepts, which will be compared with the vector of the expert. Although, the expert's vector requires a preprocessing step before comparison for reducing its dimensionality in order to examine only the sub-concepts that appear in the child's matrice. Thus, we suggest the cosine similarity technique as a comparison tool to determine the degree of similarity between the assimilation of the main concept between the child and the expert. The cosine similarity is used to calculate the similarity between two n-dimensional vectors by determining the angle between them. This metric is often used in text mining. The cosine similarity formula is as follows:

$$Cosine\ similarity = \frac{\sum_{i=1}^{n} x_i\, y_i}{\sqrt{\sum_{i=1}^{n} x_i^2}\ \sqrt{\sum_{i=1}^{n} y_i^2}}$$

Figure 5 shows the angle indicating the degree of similarity between x and y where x and y are the vectors representing the expert and child vectors respectively of scene S_α:
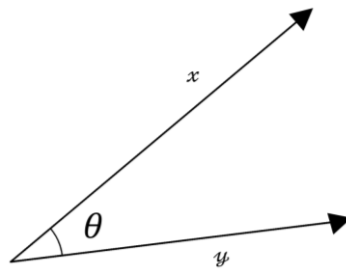

Fig. 5. Angle between vectors x and y

Taking into account the obtained result, if the angle between the vector representing the weights of the sub-concepts compared to the main concept of the child and expert is acute, the higher is the understanding of the child. Unlike, if the angle is obtuse, so the main concept is not clear to the child.

Representing the measure of a concept's assimilation by a child with ASD allows the expert to better analyze how the child perceives this concept in reality. In addition, we propose to identify the actions that have caused a significant degradation of the weights of the sub-concepts. So, for each scene, we select the actions whose weight $W_{A_{C_{\alpha_i}}} \leq 3$, knowing that:

- if $W_{A_{C_{\alpha_i}}} \leq 3$, a significant degradation is applied to the sub-concept
- if $4 \leq W_{A_{C_{\alpha_i}}} < 5$, a weak degradation is applied to the sub-concept
- if $W_{A_{C_{\alpha_i}}} = 5$, the weighting of the sub-concept does not undergo any modification

Identifying these actions will allow the expert to identify for each child the concepts that are difficult to grasp. Subsequently, the tutors should be able to adapt the learning programs, emphasizing the shortcomings revealed by the proposed technique in order to reinforce the comprehension of the child with ASD.

4   Case Study

In this part, the authors propose a case study to measure the degree of a concept's assimilation of a child with ASD using the proposed technique, the concept is "getting ready to school". The game locates the child in various situations, where he is led to interact with objects in various pieces of house in order to get ready for school. The type of the game is "simulation", presenting an environment similar to reality. The game's semantic network is developed by the expert, and it contains all the scenes forming the game, as well as the concepts and actions defined for each scene. From this model, we deduce the expert's matrice, as well as the concept weighting vector regarding to the main concept (Table 5).

Table 5. Expert's weights of concepts

Scene	*Scene* : S_α										*Scene* : S_β							
Concepts	T-shirt	Pyjamas	Sandals	Desk	Book	Backpack	Bed	Pillow	Hamper	Wardrobe	Milk	Refrigirator	Fruits	Bowl	Cooker	Pan	Floor	Cereals
Weights/ Main concept	4	3	3	2	5	5	2	1	1	2	3	2	4	2	1	4	3	5

This game allows the expert to evaluate the skills of the daily routine by simulating the real world through game scenes, a character is able to move from one piece to another and act on objects appearing in the scenes of the game. The goal is to measure the degree of assimilation of the child about his environment, his habits and his behaviors. Figure 7 illustrates two game scenes: the kitchen and the bedroom. Among the objectives of the scene happening in the kitchen, the child is led to prepare his breakfast. The objective is to evaluate if the child is able to position some tools in their correct location, also if the child differentiates between furniture and food, etc.

Fig. 6. Game scene Sα (Bedroom)

Fig. 7. Game scene Sβ (Kitchen)

Following the child's decisions through the scenes, a semantic sub-network (see Fig. 8 and Fig. 9) of the child is generated as well as the child's matrice (see Fig. 10). It includes the concepts and actions made by the child. And by applying the formula (*), we obtain the new weights of the concepts compared to the main concept. Table 6 illustrates the new concept's weights.
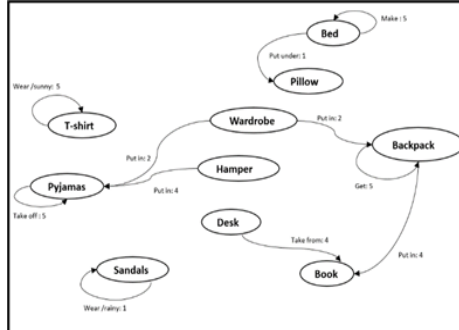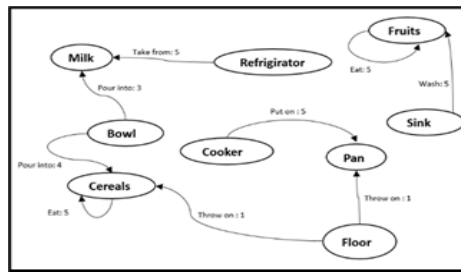
Fig. 8. Child's sub-semantic network Sα

Fig. 9. Child's sub-semantic network Sβ

$Scene_\alpha$	T-shirt	Pyjamas	Sandals	Book	Bed	Pillow	Backpack
Wear / sunny	5	0	0	0	0	0	0
Take off	0	5	0	0	0	0	0
Put in wardrobe	0	2	0	0	0	0	0
Put in hamper	0	4	0	0	0	0	0
Make	0	0	0	0	5	0	0
Put under Bed	0	0	0	0	0	1	0
Wear / rainy	0	0	1	0	0	0	0
Put in backpack	0	0	0	4	0	0	0
Take from desk	0	0	0	4	0	0	0
Get	0	0	0	0	0	0	5
Put in wardrobe	0	0	0	0	0	0	2

$Scene_\beta$	Milk	Cereals	Pan	Fruits
Pour into bowl	3	0	0	0
Take from refrigirator	5	0	0	0
Eat	0	0	0	5
Pour into bowl	0	4	0	0
Wash in sink	0	0	0	5
Put on cooker	0	0	5	0
Throw on floor	0	0	1	0
Throw on floor	0	1	0	0
Eat	0	5	0	0

Fig. 10. Child's matrice

Table 6. Child's weights of concepts

Scene	Scene : S_α							Scene : S_β			
Concepts	T-shirt	Pyjamas	Sandals	Book	Backpack	Bed	Pillow	Milk	Fruits	Pan	Cereals
Weights / Main concept	4	3	3	5	5	2	1	3	4	4	5

The goal is to measure if the child understands the concept "getting ready to school", this evaluation takes as parameter the vectors of the child and the expert including the weights of the concepts (see Table 5 and Table 6). We obtain by applying the cosine similarity technique, for the scene α (Bedroom) a value of angle separating the vectors of the child and the expert which is equal to: $\theta = 25°$ (see Fig. 13), whose cosine is equal to: $\cos(V_{child}, V_{expert}) = 0.9$. For the second scene β which corresponds to the kitchen (see Fig. 14), the measure of similarity between the sub-concepts of the child and the expert is estimated to $42°$.
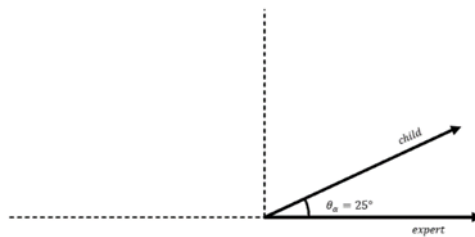

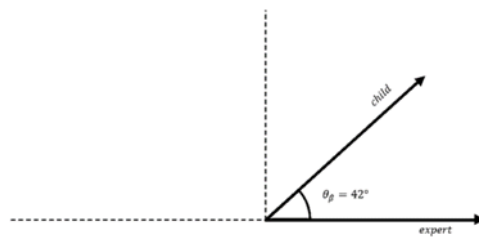**Fig. 11.** Angle between expert and child concepts (S_α)

Fig. 12. Angle between expert and child concepts (S_β)

Besides, we notice that the child partially masters the concept "getting ready to school". Moreover, he understands the missions linked to the bedroom much better than

those linked to the kitchen. Next, we determine the actions that caused a significant degradation in the concept's weights.

For the "Kitchen" scene, the actions are:

- Put pyjamas in wardrobe
- Put pillow under bed
- Wear sandals on a rainy day
- Put backpack in wardrobe

For the "Bedroom" scene, the actions are:

- Pour milk into bowl
- Throw cereals on floor
- Throw pan on floor

After identifying actions that have considerably influenced the weights of the concepts, we can clearly see that for example for the child has difficulty assimilating the notion of the weather, to choose the suitable shoes to wear when it rains. About, the child emitted the same action "throw on floor" twice which can be translated by an aggressive behavior which reflects a sign related to the ASD or it comes from another origin. The interpretation of the results of the technique provided by the expert requires the intervention of tutors and parents to ensure proper support for the child with ASD.

5   Discussion

Feedback and evaluation are inseparable from educational objectives and learning activities. The proposed technique aims to measure the degree of assimilation of a concept by a child with ASD at preschool age; it is an innovative and potentially powerful tool to assess this degree of assimilation through serious games. Indeed, the serious games sector is a promising area because it constitutes an excellent test bench, as well as a field of application, for evaluation. The technique offers several advantages such as:

- Allowing regular monitoring of the child's progress helps keep learning objectives in mind so the tutors can help dispel ambiguous concepts in the child.
- Take advantage of children's engagement in playful environments to tacitly assess their understanding on a given concept.
- Identify continuous improvement strategies.

Nevertheless, describing all the possible reactions of the child proves to be a difficult step for the expert because he must define all the reactions that can be carried out in the space of the game. However, the assessment for learning refers to more than just a form of assessment, rather it encompasses an approach to education and learning whereby the tutors and parents are constantly informed of the development of the child learning.

6   Conclusion

Evaluation is used for a variety of purposes, one of the major goals is to foster learning. Evaluate in order to provide a precise and personalized learning assistance to the learner. As well as evaluating a child's activity, performance or progress is often a great way to improve and validate learning. In this article, we propose a technique for evaluating the degree of assimilation of an autistic child, it is carried out during learning and will help tutors to identify concepts not well assimilated by the child, to become aware what the child has already learned or what remains to be learned.

The proposed technique uses serious games as a tool to measure children's reactions in game scenes in a tacit manner. It will assess metacognitive control, in other words, how the child builds and uses his own knowledge.

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