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Assessing Children's Perceptions of Live Interactions With Avatars: Preparations for Use in ASD Therapy in a Multi-Ethnic Context

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ABSTRACT Avatars have been found to be useful tools to overcome communication barriers in people affected by Autistic Spectrum Disorders (ASD) and to help them understand and express emotions. However, it has been shown that the success of the interactions is highly dependent on the subject's identification with the avatar. In this study, we assess the variables that may influence that perception in children under 10, in the context of the largely multi-ethnic Ecuadorean society. The results reveal that, unlike previous studies showed for young adults, the ethnic traits displayed by the avatars are not a critical factor, as the the quality of the interactions was more influenced by the perception of the avatars' appearance, their similarity with the kids' peers and, above all, the ability of the human model who controls the avatar to use a pleasant voice, to succeed in making his/her questions and responses fully understood, and to master the non-verbal communication transmitted through gestures and voice.

INDEX TERMS Avatars, human-computer interaction, multi-ethnic societies.

I. INTRODUCTION

The increasing use of Virtual Reality elements in processes of human-computer interaction and interaction between people opens up numerous possibilities and applications in different areas [1], [2]. In particular, interaction with avatars or virtual agents has become popular in recent years [3], attaining notable results in areas of tourism [4], [5], entertainment [6], [7], healthcare [8], [9], education [10], [11] and psychology [12]–[14], among others.

In this article we are interested in the use of avatars in the treatment of Autism Spectrum Disorders (ASD). ASD refers to a range of neurodevelopmental disorders that cause persistent deficiencies in social communication, making it difficult or impossible to initiate or maintain an interaction. Also, it is often manifested through the so-called *Restricted and Repetitive Behaviors* [15], [16], which may include stereotyped movements, compulsive and ritual behaviors, reiterated self-harm, rigidity, inflexibility and, finally, very intense, persistent and invariable interests or preferences [17].

Avatars have proven to be useful tools to break communication barriers in people with ASD [18], [19] or to help them understand and express emotions [20], [21]. However, considering that people affected by ASD may have very different preferences and behaviors, when developing avatars for therapeutic purposes it is necessary to consider that individuality. Experience (see [22], [23]) shows that the patient's first contact with the avatar is critical: if communication does not flow well already in the first session (e.g. due to processing delays, glitches, rejection of the avatar's appearance or the

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tone of voice of the person who controls it, etc.), then it is very likely that it will not be possible to conduct avatar-mediated therapy.

In the framework of the UNESCO Chair on Supporting Technologies for Inclusive Education, we have created a technological solution to deliver ASD therapy mediated by avatars to children in the society of Ecuador. Ecuador is an intercultural, plurinational and multi-ethnic country, in whose territory dozens of ethnic groups exist: many present since pre-Hispanic times, and others that were born from the Spanish conquest and the arrival of Afro-descendants. Where Hanratty [24] spoke in 1991 of four large groups (white, black, mestizo and Indian) that would cover all existing ethnic groups, the last census carried out in the country in 2010, in relation to ethnic self-identification according to culture and customs, indicated that in Ecuador there are: 71.9% mestizo, 7.2% Afro-Ecuadorian, 7.0% indigenous, 7.4% montubio, 6.1% white, and 0.4% from a different ethnic group [25].

In this context, once our technological solution was built and optimized so that the technical aspects did not hinder the therapy [26], [27], we wanted to evaluate its acceptance by 8- and 9-year-old children, in an experiment in which they could select one avatar among several, with different ethnic traits. In order to avoid risks of causing frustration and rejection, we did not involve ASD children but rather worked with regular (neurotypical) ones, aiming to assess the variables that may influence their identification with the avatars. This approach is backed up by the study of Parsons *et al.* [28], who found that, despite the notable differences in social skills, children and teenagers affected by ASD tend to follow the same preferences as neurotypical ones in virtual environments. Likewise, Beuminger and Shulman [29] found that the preferences regarding who to befriend have largely similar influences for both cohorts.

Contravening the results of previous studies (conducted with young adults), our experiment reveals that the ethnic traits displayed by the avatars are not a critical factor as we initially expected, inasmuch as kids under 10 may be still unaware of their own ethnicity. Boys and girls tended to express greater neutrality about the ethnicity than the gender of the avatar, yet there was a clear bias in their choices towards white avatars, to the detriment of mestizo and, especially, black ones.

The paper is organized as follows. Section II provides an overview of previous works in the use of VR technologies in relevant areas of healthcare. Section III presents the features of the system we have created for avatar-mediated therapy. Section IV describes the experiment we have conducted to assess the variables affecting the election of one particular avatar; Section V presents the results and Section VI provides the corresponding discussion. Conclusions and future work are given in Sections VII and VIII, respectively.

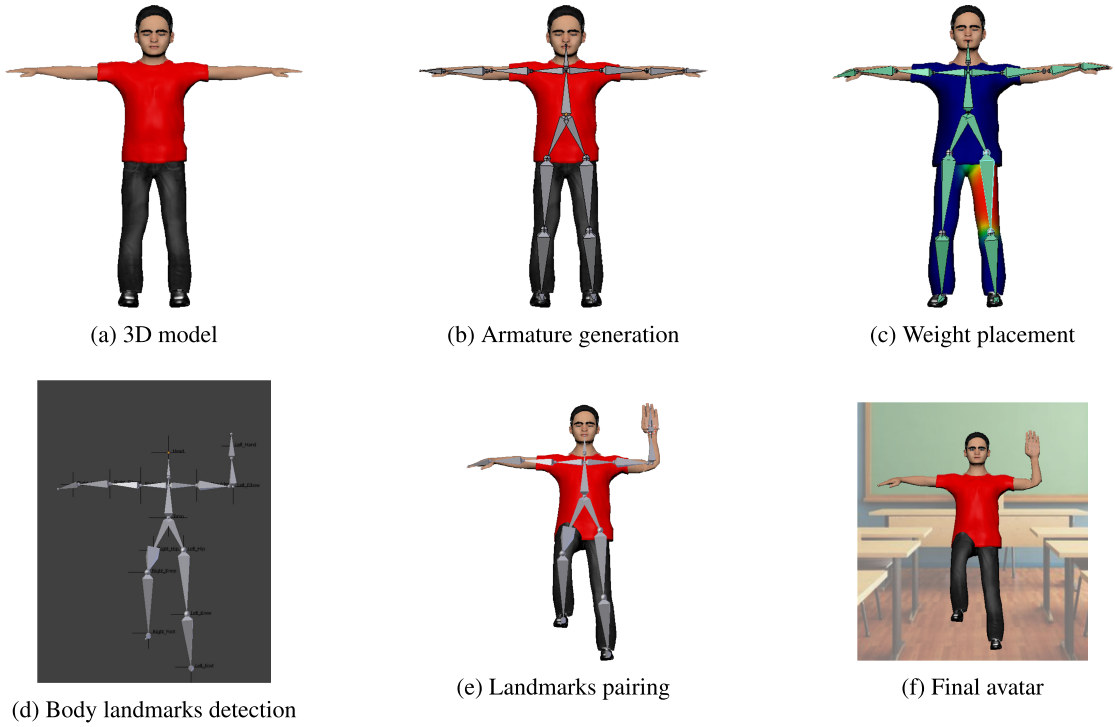
II. RELATED WORK

Applications of Virtual Reality have been tested to support different psychological and neurocognitive interventions related to post-traumatic stress, obsessive compulsive disorder, psychotic disorders and weight-related disorders, among others. Rizzo and Bouchard [30] published a survey in which they highlighted the value of creating virtual environments or characters according to the characteristics of the particular psychopathy or the neurocognitive disorder to intervene. They mentioned other advantages related to the ability to produce emotionally evocative therapeutic experiences, to replicate physical activity in comfortable and controlled conditions, to reproduce complex interactions and clinical training, and to provide multisensory opportunities to promote learning and transfer of new skills.

VR has received special attention in the treatment of ASD [31]–[35]. Ahmad *et al.* [36] highlighted a clear trend towards the use of multimedia resources in education, given the fact that ASD children frequently have strong visual-spatial skills, non-verbal problem-solving skills, and visual and auditory memory. Several studies demonstrate the effectiveness of the use of VR also in therapeutic processes, especially due to the possibility of creating controlled environments and virtual characters, reducing the anxiety generated by real social situations [37]–[41]. Thanks to the use of technology, it has been possible to improve therapeutic processes in social [19], [42], emotional [20], [21] and academic aspects [43]. In this context, the development of virtual agents or avatars is a specific topic within VR, which has received special attention due to its efficiency when interacting with people with ASD [44], [45]. Their effectiveness can be compared even to the use of robotic tools and interaction with peers [46].

Charlton *et al.* [47] showed that avatars function as tools to improve the level of commitment, helping therapists during interventions and presenting advances in the acquisition of social skills. Another advantage is the possibility of simulating non-verbal language accompanying verbal language, i.e. including in the avatar characteristics such as proximity, orientation, joint attention and gestures, achieving interactions closer to reality. Wang *et al.* [48], on the other hand, presented promising results when combining verbal and non-verbal language during the interaction of avatars with people with ASD. Other authors have demonstrated the effectiveness of working with avatars in different therapeutic processes for people with ASD, functioning as tutors in the teaching of social and communication skills, as emotional regulators and in the recognition of facial expressions [20], [44], [49]–[54].

One of the ideas that are commonly mentioned in the aforementioned works is the need to personalize the tools used with ASD subjects, in order to increase empathy and identification towards the avatars [55]. Considering that each person diagnosed with ASD has specific characteristics and very marked preferences that differentiate them from others, it cannot be assumed that there are general processes or tools



(a) 3D model (b) Armature generation (c) Weight placement

(d) Body landmarks detection (e) Landmarks pairing (f) Final avatar

FIGURE 1. Body recognition and animation process.

that can serve everyone. Usually, personalization has been made based on the diagnostic characteristics represented by the Restricted and Repetitive Behaviors, and in particular the *Restricted Interests* (RI). These refer to a narrow range of objects or activities toward which people with ASD show intense and focused interest [56]; they are present from very young ages and can be persistent throughout life [57]. The usefulness of the RIs in therapeutic interventions is based on the fact that they represent islands of abilities in specific subjects for individuals, so that they can be considered as strengths and bridges to improve other abilities [23]. There is also evidence of their usefulness as motivators in the academic realm [22], [58] and as references to adapt study programs [59], as the interaction with the avatars improves if they display elements related to the RI in their appearance, their gestures or the contents they show.

In this paper we study personalization in relation to introducing aspects of ethical or racial identity in the design of avatars. In areas of entertainment and consumption, it can be considered proved that the customization of physical traits increases empathy and identification towards avatars [60]. Likewise, there are studies that demonstrate the importance of the ethnic characteristics of avatars to achieve effective communication [61]–[64]. In general, when a person chooses or designs her own avatar or virtual representation, she tends to use characteristics that reflect her self-perception in the real world, even if the options she can choose from may not always meet her expectations, due to demographic or contextual factors (e.g. the country where the application was developed compared to the country where it is used) or to the fact that the anthropomorphic characteristics of the avatars are developed based on stereotypes [65], [66]. In the field of education, Brown *et al.* [67] and Lee [68] argue that avatars with ethnic characteristics provide greater possibilities of interaction, creating culturally diverse and inclusive virtual worlds. The impact of ethnic aspects is much less investigated in healthcare areas, although the ethical implications of interactions among patients and healthcare providers in virtual environments have been discussed [69]. Our work aims to corroborate whether the general consensus on the improvements due to the ethnic characterization of avatars extends to the field of VR-supported ASD therapy, with particular attention to the perceptions of children under 10.

III. OVERVIEW OF OUR SYSTEM FOR AVATAR-MEDIATED ASD THERAPY

The system we have developed consists of a set of devices used to capture and transmit the voice, the movements and the facial expressions of human models to avatars, which are used as virtual puppets. The main devices are:

- A microphone to transmit the voice.
- A Kinect sensor to capture body movements.
- A webcam for facial recognition.
- A video camera to record the kids' interactions with the avatars.

Voice is transmitted directly to the final stage, just going through a normalization filter. Facial recognition and motion

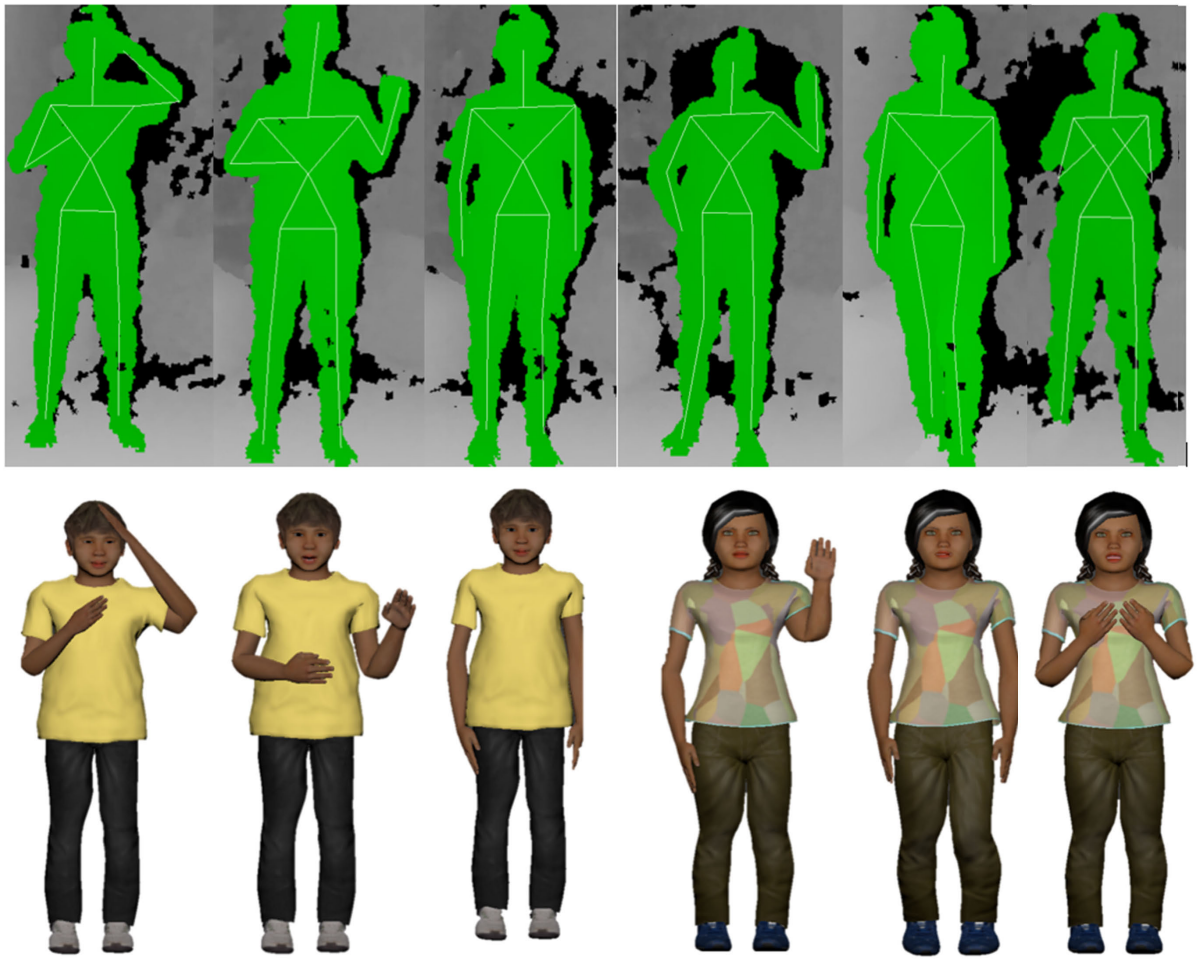


FIGURE 2. Body animation examples using Kinect sensor.

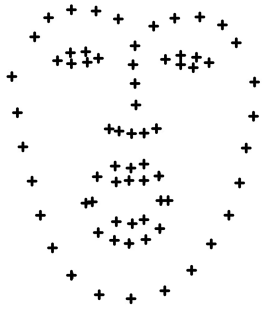
capture, on the contrary, depend on intensive AI processing, as explained in the following subsections. Similar processes for the animation of 3D models were detailed in previous publications [26], [27].

Figure 1 shows the process to animate the avatars. Starting from 3D models previously created in Blender (Fig. 1a), we start out by generating an armature that plays the role of the body bones (Fig. 1b). Our system uses only 18 of these elements, located in the main joints. The central bone (located in the lower part of the torso) makes the total follow-up of the body and provides a reference for the movement of the rest of the bones. After completely creating the armature, it is necessary to link it with the 3D model and assign weights based on the deformation necessary in each joint to achieve natural movements (Fig. 1c). The correct allocation of weights allows each part of the body to move in a coherent way (e.g. so that when moving the hand, the forearm and the arm have the proper chained movement).

Once the desired movement has been achieved, the multispectral camera and the Kinect sensor are used to detect body shapes and gestures (Fig. 1d). Using the NI Mate library, the human pose is estimated and coordinates are generated to later link them to the bones of the armature (Fig. 1e). Finally, a nice background is added (Fig. 1f). The lower part of Fig. 2 shows examples of the mestizo boy and girl avatars, animated from the reference points captured by the Kinect sensor as shown above.

The process for facial animation is similar to that used for the body, with the difference that we use a webcam instead of the Kinect sensor. Through the OpenCV library, facial detection algorithms are applied to identify reference points within the face. The algorithm uses regression trees to estimate 68 reference points (Fig. 3a), located in strategic areas: eyebrows, eyes, nose, mouth and jaw. Once those points have been detected, they are again imported into Blender and incorporated into the bone armature. This is linked to the 3D model and a full weight assignment is made to ensure proper deformation of each expression line. After assigning the weights, it is possible to move the expression lines of the avatars and simulate gestures (Fig. 3b).

This system has two remarkable characteristics for its use in schools throughout Ecuador and other countries. On the



(a) Facial landmarks detection.

(b) Placing facial points on the avatar's face.

(c) Happy

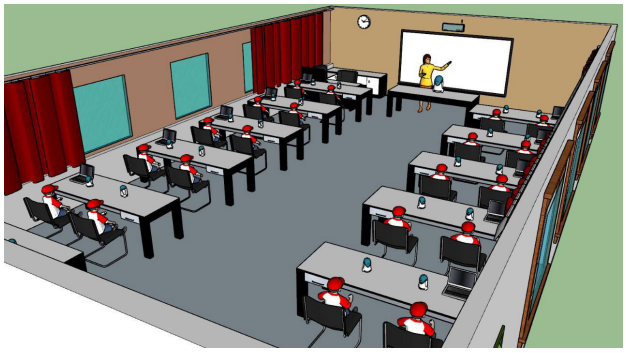
(d) Attentive

(e) Sad

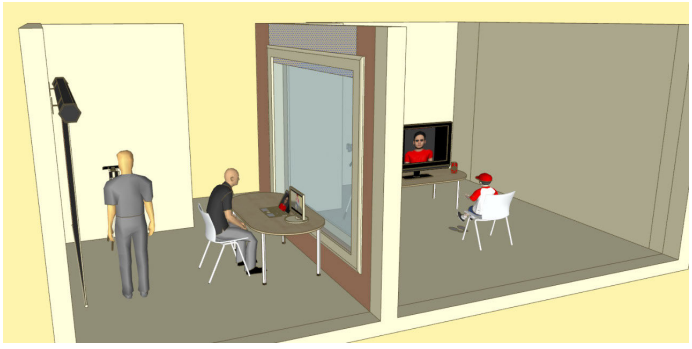
(f) Angry

(g) Hostile

FIGURE 3. Landmarks and face animation.



(a) The waiting lounge.



(b) The observation area and the working area.

FIGURE 4. Locations of our experiment.

one hand, its cost is very low because it involves accessible consumer devices, rather than the advanced equipment (3D vision helmets, controls, wearables, etc.) of other VR-based human-computer interaction systems. On the other hand, the implementation as open source avoids the need to purchase licenses and allows the software to be shared with other researchers, opening the possibility of receiving contributions and improvements from any interested parties.

IV. EXPERIMENT DESIGN

Our experiment was developed within a Gesell chamber, so that the human models controlling the avatars could see the participants' reactions, while the latter were not influenced by the presence of additional people. There were four different locations:

- Waiting lounge (Figure 4a): this is where the children gathered in a group, together with a tutor, to be provided with indications on the process that would follow. Several engineering students organized a demonstration of social robots as a side event, with the aim of keeping the participants relaxed and willing to participate.
- Entry area (outside of the location shown in Fig. 4b): the children arrived here to begin their individual interaction with an avatar, which they would have to select from 6 different models, differentiated by their gender and ethnic group (Figure 5). Among the groups present in the Ecuador census, we have built mestizo, Afro-Ecuadorian and white avatars. We have not initially added the indigenous and montubios because their physical features are similar to those of the mestizos, mainly varying their clothing, and this is a variable that we leave for a later phase of our project, as we will explain in Section VII.
- Observation zone (left hand side of Fig. 4b): here were the human models who controlled the avatar; they could see and hear the child but not vice versa. They had been instructed to maintain the same style with all the

(a) White girl (Sophia) (b) Mestizo girl (Paola) (c) Afro-Ecuadorian girl (Pamela)

(d) White boy (Pablo) (e) Mestizo boy (Felipe) (f) Afro-Ecuadorian boy (David)

FIGURE 5. A set of avatars based on ethnic groups.

children, going through a series of 16 questions aiming to maintain a fluid dialogue for at least 3 minutes. So, to start the interaction, the avatar began by greeting with the phrase: "Hello, my name is `[name of the selected avatar]`. Let's have a conversation. Sit back, get comfortable, and let's get started." After the participant sat in front of the screen, the avatar began to ask the following questions:

- "What's your name?"
- "How old are you?"
- "When is your birthday?"
- "What is your favorite color?"
- "Do you like or practice any sports?"
- "Would you like to have superpowers?"
- "How many people live in your house and what are their names?"
- "Do you have a pet? If so, what's its name?"
- "What animal would you like to have as a pet?"
- "What would you like to be when you grow up?"
- "Did you travel during the last holidays? If so, where?"
- "Where would you like to travel with your family?"
- "How many friends do you have?"
- "What are the names of your best friends?"

Every four questions, the human models would ask the control question "Do you want to continue chatting?". If the answer was positive, the script continued, but otherwise it went directly to the farewell, in which the avatar would say "That was all for today, thank you very much for answering all my questions. I hope you had fun. See you another time!".

- Working zone (right hand side of Fig. 4b): this is where the children interacted with the chosen avatar. Figure 6 shows the picture of a kid during the experiment.

Upon ending the interaction with the avatar, the child went back to the entry area and replied to a 20-question survey (Table 1), which provided the data that we will discuss in Section V. The first 3 questions sought to gather demographic information about the participants, which were taken as the independent variables of the study: gender, neighborhood (which in Ecuador serves an indirect indicator of socioeconomic position) and age.

The next 17 questions were posed to assess the dependent variables. In Table 1 these questions are related to the respective variables, as well as the ones of the model proposed by Hamman to evaluate quality of experience in virtual environments [70]. Additionally, we have considered the variable of naturalness, as recommended by Weiss *et al.* [71]. All these variables were rated using a 5-point Likert scale (1 being the most negative value and 5 the most positive), except "Mood perception", for which there were 6 choices: joyful, serious, sad, boring, angry and nervous.

V. RESULTS

As participants in the study we had 31 primary school students (13 boys and 18 girls, aged between 8 and 9) from the "Mariana de Jesús" Private Educational Unit of the city of Cuenca, Ecuador. According to the official records provided

FIGURE 6. A boy and a girl during interaction with the avatar.

TABLE 1. Questions used to evaluate the interaction with the avatars, linked to experiment variables and reference models.

Question	Experiment variable	Hamman/Weiss dimensions – variables
What is your gender: boy or girl?	Demographic information	–
What is the name of your neighborhood?		
What is your age?		
1. What avatar do you look more like?	Ethnic identity	Perception measure – Involvement
2. Did you like today's avatar?	Satisfaction	Perception measure – Satisfaction
3. Would you have enjoyed the same with the other [mestizo/Afro-Ecuadorian/white] avatar?	Gender neutrality	Perception measure – Engagement
4. Which [boy/girl] avatar would you choose the second? Would you have enjoyed the same with [him/her]?	Ethnic neutrality	Perception measure – Engagement
5. Did you like the way the avatar greeted you?	Interaction opening	Perception measure – Motivation
6. Did you like the clothes the avatar wore?	Appearance	Rendering quality – Graphics
7. Did you like talking with the avatar?	Communication	Perception measure – Satisfaction
8. Did you understand what the avatar said?	Speech quality	Rendering quality – Audio
9. Did you like the avatar's voice?	Voice	Perception measure – Naturalness
10. Did you like the way the avatar moved?	Animation	Perception measure – Naturalness
11. Did the avatar scare you at some point?	Emotion/scare	Psychological measure – Emotions
12. Would you like to talk to the avatar again?	Engagement	Perception measure – Engagement
13. Would you like to have the avatar at school?	Usefulness at school	Perception measure – Usefulness
14. Would you like to have the avatar at home?	Usefulness at home	Perception measure – Usefulness
15. Do you think the avatar looks like your classmates and/or relatives?	Similarity with peers	Perception measure – Presence
16. Did you like the way the avatar said goodbye?	Interaction closing	Perception measure – Motivation
17. Did you like the mood of the avatar?	Mood perception	Psychological measure – Emotions

by the school, all the students belonged to the mestizo ethnic group. However, they were asked about the gender and ethnicity with which they identified themselves when covering the survey after interaction with the avatar.

Table 2 summarizes the values obtained for the demographic variables of our study. It must be noted that all the children indicated their gender in accordance with the official records, and that they all chose the same gender for the avatar. On the other hand, in relation to ethnicity, 23 participants (74.19%) self-identified with the white ethnic group, while 6 (19.35%) did so with the mestizo ethnic group and 2 (6.45%) with the Afro-Ecuadorian ethnic group. This fact provides first evidence that ethnic identity may not be a fully assimilated concept for children at this age.

As shown in the diagram of Fig. 7, most of the participants chose an avatar of the ethnic group with which they self-identified. The following observations should be made:

- 25 participants (80.65%) decided to interact with the white avatars, 6 (19.35%) with mestizo ones, and none chose the Afro-Ecuadorian avatars.

TABLE 2. Summary of the demographic variables and avatar selections.

Variable	Male	Female
Official gender	13	18
Gender identity	13	18
Avatar gender	13	18

Variable	Mestizo	Afro-Ecuadorian	White
Official ethnicity	31	0	0
Ethnic identity	6	2	23
Avatar ethnicity	6	0	25

- All the boys chose the male white avatar, including the one who identified himself as mestizo and the 2 who identified themselves as Afro-Ecuadorians. As second choices, 8 out of the 13 boys (61.54%) opted for the mestizo avatar and 5 (38,46%) chose the Afro-Ecuadorian one. The boys who had self-identified as mestizo or Afro-Ecuadorian made their second choices correspondingly.
- Among the girls, 12 (66,67%) chose the female white avatar: 11 of them had self-identified as white and 1 as mestizo. 6 girls (33,33%) chose the female mestizo

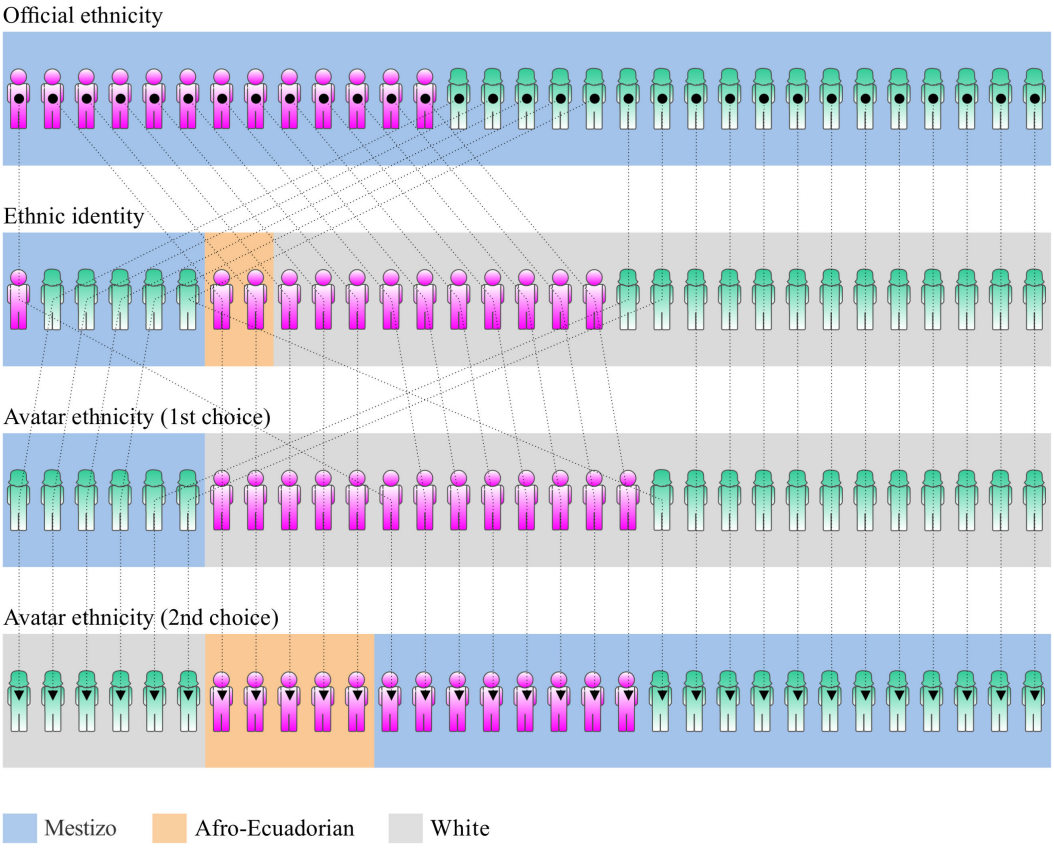


FIGURE 7. Boys and girls' official ethnicity, identity and avatar selections.

avatar: 4 of them had self-identified as mestizo and 2 as white. As second choice, the one who had chosen mestizo chose white, and vice versa.

In the variables "Ethnic identity" and "Avatar ethnicity", thus, we observe a clear bias towards white, plus neglect for Afro-Ecuadorian (especially among girls). This may be a reflection of the stereotypical models existing in the multimedia content that the participants are used to consuming, since the vast majority of the characters in popular apps and games in Ecuador are white, with no trace of the country's ethnic characteristics. It is worth noting that our analysis did not reveal any statistically-significant influence of the socioeconomic level in this perception, which might nonetheless show up in studies involving larger and more diverse cohorts, and considering more direct indicators than neighborhood.

Table 3 shows the values of mean, mode and variance for the variables that we measured with the Likert scale. It is observed that the mode (the most frequent value) is at the highest level of the scale (5) for most variables, yielding means above 4 and very low variances. Likewise, the majority (80.65%) of the participants perceived that the avatar was joyful. Therefore, the evaluation of the children's satisfaction with the experience can be considered high. There are two points worth discussing, though:

- The fact that "Similarity with peers" has mode 3 reveals that the participants considered the avatars to be only slightly similar in appearance to their peers. This may be considered low, if the goal is to achieve the highest level of identification with the avatars.
- The variable "Emotion/scare", while having mode 5 ("The avatar never scared me"), had a low average value and the highest variance, because a few kids noticed some frames of distorted avatar faces during short periods that the human controllers rotated their heads and confused the gesture recognition AI.

More interesting for this study is the fact that "Gender neutrality" had a majority of children indicating 4, meaning that interacting with an avatar with the same ethnicity they had chosen but a different gender would have been "good" but not "very good". This reinforces the finding that gender is a strong preference, whereas ethnicity is slightly weaker. However, "Ethnic neutrality" has larger variance, as some children said they would dislike interacting with an avatar with the same gender they had chosen but a different ethnicity. It is worth noting, in particular, that one girl who had self-identified as white replied that it would have been "very bad" to interact with the mestizo girl avatar (her second choice), whereas she said it would have been "very good" to interact with the white boy avatar.

For a more in-depth analysis of the results and the influences among the quantitative variables, we applied the Ordinary Least Square (OLS) regression method, which yielded the correlation values that are represented in Fig. 8. From the intensity of the colors, we have a quick idea of the level

TABLE 3. Summary of the quantitative variables of our study.

Variable	Mean	Mode	Variance
Satisfaction	4.48	5	0.44
Gender neutrality	4.00	4	0.52
Ethnic neutrality	4.29	5	0.85
Interaction opening	5.00	5	0.00
Appearance	4.87	5	0.24
Communication	4.71	5	0.27
Speech quality	4.61	5	0.69
Voice	4.61	5	0.62
Animation	4.42	5	1.21
Emotion/scare	3.48	5	2.51
Engagement	4.19	5	0.93
Usefulness at school	4.37	5	0.83
Usefulness at home	4.10	5	1.44
Similarity with peers	3.03	3	2.10
Interaction closing	4.81	5	0.35

Variable	Joyful	Serious	Sad	Boring	Angry	Nervous
Mood perception	80.65%	12.90%	0%	0%	0%	6.45%

Variable	Average for boys	Average for girls
Interaction time	2 min 10 s	3 min 41 s

of correlation between each pair of variables: a value close to +1 indicates a direct relationship (the greater the value of one variable, the greater the value of the other); a value close to −1 indicates inverse proportionality (the higher the value of one variable, the lower the value of the other) and a value around zero suggests no correlation. In this analysis we include both ''Gender identity'' and ''Avatar gender'' because, having only two possible values, the only effect of assigning 1 and 2 values one way or the other is a change of sign in the correlation, but the absolute value remains useful. Specifically, we have used 1 for ''male'' and 2 for ''female''.

Besides the known fact that ''Gender'' and ''Avatar gender'' are 100% correlated, the OLS analysis reveals that the liking of the avatar's ''Appearance'' correlates positively with the perceived ''Similarity with peers'', which in turn correlates negatively (though slightly) with ''Ethnic neutrality''. In other words, ''Appearance'' and ''Similarity with peers'' are greater for those with stronger ethnic preferences, which reinforces the idea that ethnic aspects (look, clothing, accent, etc.) may be important to increase the level of identification and familiarity with the avatars.

Other findings from the OLS analysis have to do with the quality of the experience rather than with preferences in the selection of one avatar. These are important findings to bear in mind when involving ASD children:

- On the one hand, the valuation of ''Speech quality'' correlated positively with ''Gender'', meaning that woman who controlled the female avatars made herself easier to understand than the man who controlled the male ones. This could be one of the factors contributing to a more satisfactory experience, evidenced by the greater values that girls generally gave to ''Satisfaction'' and their longer interactions (see average values of ''Interaction time'' in Table 3).
- In the same line, liking the avatar's ''Voice'' seems to be a key factor towards a positive experience, as it correlates positively with most of the variables in Hamman's ''Perception measure'' dimension.
- The only exceptions to the previous point happen in the cluster formed by the variables ''Engagement'', ''Usefulness at school'' and ''Usefulness at home'', which only correlate positively with themselves. With the aid of the children's tutor, we found that the reason had to do with the fixed script we had created for the experiment, which included very generic questions. In such conditions, the boys and girls who had enjoyed the experience the most –particularly, the ones who went through all the questions– thought it was all over and, therefore, saw little reason to continue chatting with the virtual stranger in any context.

VI. DISCUSSION

The results reinforce the fact –widely documented in the literature– that the avatar's gender must match the kid's gender in order to ensure fruitful interactions. On the contrary, the ethnic traits displayed by the avatars turned out not to be a critical factor with participants younger than 10, as they seemed to be unaware of their own ethnicity and, besides, they clearly expressed greater neutrality about the ethnicity than the gender of the avatar. The quality of the interactions was more influenced by the perception of the avatars' appearance, their similarity with the kids' peers and, above all, the ability of the human model who controls the avatar to use a pleasant voice, to succeed in making his/her questions and responses fully understood, and to master the non-verbal communication transmitted through gestures and voice.

Nevertheless, our experiment has verified the influence of the stereotypes frequently used in the media: due to the wide consumption of TV programs, video games and mobile applications with characters that adhere to the prototype of a human belonging to the northern hemisphere, with well-established ethnic or racial characteristics, consumers tend to choose those same characteristics when using VR tools. It is even observed that the exposure to multimedia material with non-Latin American characters can modify the way in which children define themselves in terms of their ethnicity. Although children receive information —both at home and in schools— that places them in an ethnic group of the Ecuadorian census, there is no coherence with the characteristics that they can identify in their self-definition.

Taking into account the ethnic diversity of Ecuador, the need to include these characteristics in the multimedia

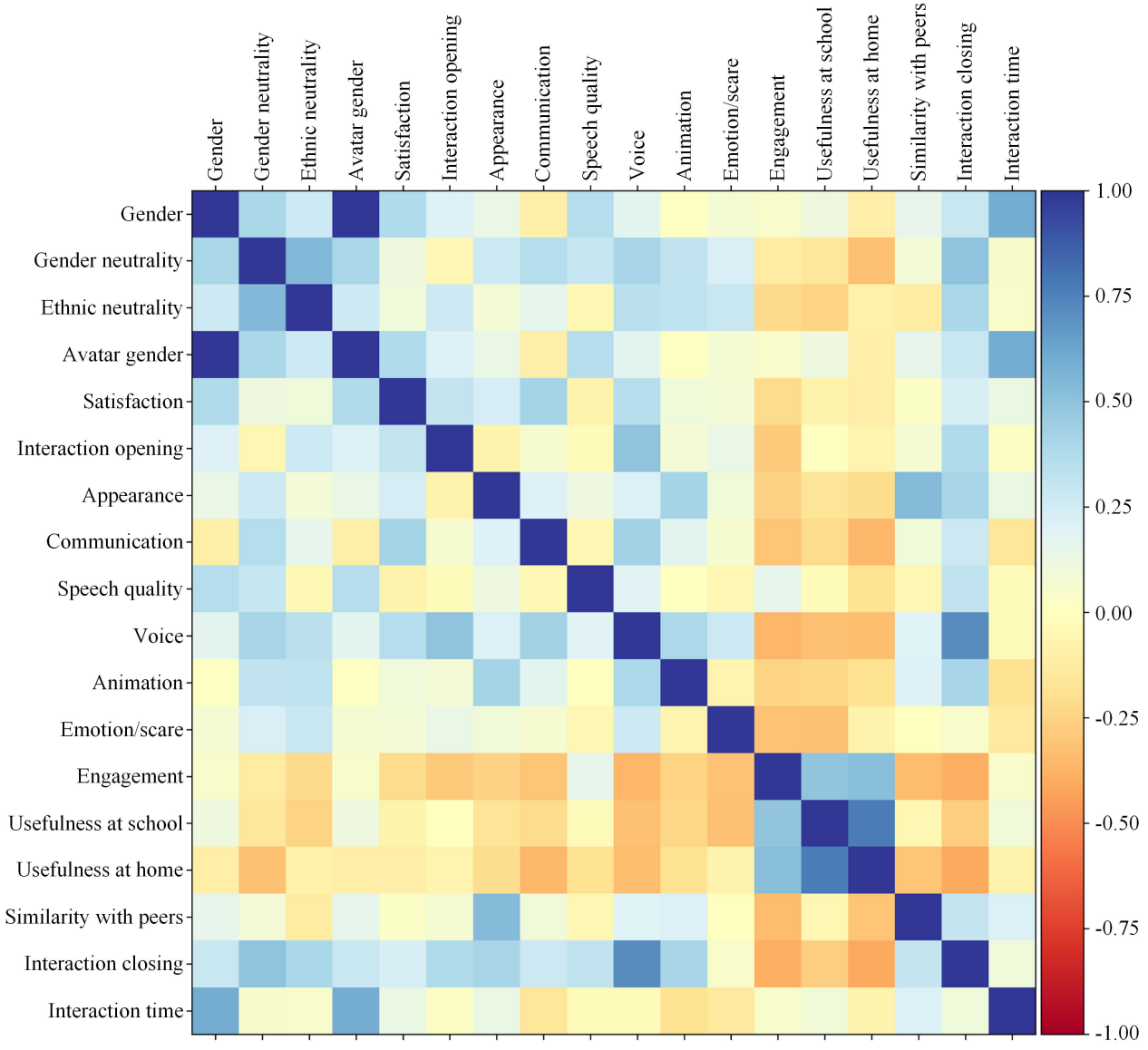


FIGURE 8. Representation of the correlation analysis of the experiment variables using OLS.

content developed in the country should be considered. Excessive consumption of imported material influences the perception of ethnic identity. The development of avatars and video game characters with ethnic characteristics could be considered, therefore, as a contribution to the recovery of identity and, at the same time, to the preservation of the intangible heritage of the nation.

One result that cannot go unnoticed is that none of the participants chose the avatars of Afro-Ecuadorian ethnicity, even though two of them self-identified within that group. Although this can be attributed to the influence of social stereotypes present in multimedia resources, it also raises a series of questions regarding possible racial discrimination (conscious or unconscious). This hypothesis makes sense when considering that within Ecuador there are still social prejudices related to this ethnic group. Although discrimination is less common in children, the influence of adults can generate erroneous criteria that lead to some type of prejudice.

The use of avatars, as explained in Section II, has shown great potential to improve the treatment and lifestyle of people with disabilities. The first developments focused only on training specific skills, with unique avatars designed with a one-size-fits-all approach. Currently, there is greater interest to engage the subject users by considering their tastes and interests. Up to now, there were no specific studies on the influence of ethnic traits on the design of avatars for use with people with disabilities; however, it was known that the general appearance of the avatar has an impact in the effectiveness of therapeutic interventions. The results of our study show that ethnic characteristics do have an influence on the selection of avatars and that, in addition to reinforcing

the therapeutic processes, they may be harnessed to increase self-identification and to fight against discriminatory tendencies and social prejudices.

VII. CONCLUSION

This first stage of our project has revealed strengths and weaknesses of an avatar-person interaction system in a multi-ethnic society. The evaluation of the system with neurotypical children serves as a reference regarding the details that must be considered when interacting with ASD children.

Our experiment has shown that the ethnic characterisation of the avatars, while not as critical as gender differentiation, help to increase the opportunities to attain greater levels of identification and familiarity with the avatars. Having ensured this, the avatars can successfully convey non-verbal language, which is essential to handle emotional aspects, to increase the attention span and to engage in long-lasting interactions. This is harder to achieve with other technological tools for ASD therapy, such as robots controlled by humans behind the scenes (see [72], [73]). Besides, the computer-generated avatars are advantageous for reasons of availability and adaptability:

- On the one hand, in many countries it cannot be expected that most families of ASD children —just like their schools and points of care— can invest in purpose-specific robotic equipment. On the contrary, TV screens are almost everywhere, and the multiple uses of computers and Internet connections (e.g. for leisure, education and work) render a more propitious environment for the adoption of systems like ours.
- On the other hand, when working with computer-generated avatars rather than physical ones, it is much easier to modify their appearance in order to further increase the levels of identification and familiarity by matching the interests and preferences of each subject (see Section VIII for our future work in this regard). The environment surrounding the avatar can be customized, too.

One shortcoming of the computer-generated avatars, in comparison with the robotic ones, is the fact that the latter appear on the flat surface of a screen, which many parents, educators and caregivers consider inconvenient in an era in which children spend many hours watching screens already, including smartphones, tablets, gaming consoles, TVs and computers. It is up to the human controllers to drive the avatar-kid interaction so as to incite tactile stimuli, for example through the use of toys and tools.

It is the authors' opinion that this type of advances (avatars, robots, AI systems processing the data gathered during interventions, etc.) are not intended to replace the therapists, because their know-how is key to achieving results in the complex area of ASD, where each subject poses a particular challenge due to his/her specific interests, preferences and needs. Indeed, we believe that mastering the skills of designing effective therapy plans for ASD —and adapting them based on the observed progress— is one of the greatest challenges that may be faced in the area of AI-based expert systems. Therefore, in our view, the aim is to provide means and assistance to therapists to maximize the usage of their time. Along these lines, there are proposals aimed at speeding up diagnoses, identifying cases similar to a given one, sketching possible therapy plans based on the results of plans applied in the past with those similar cases, etc. In such an ecosystem of technological aids, our system could be incorporated in three stages:

- During the first sessions with each subject, two therapists would work: one next to the child, spurring the interaction and supervising that the avatar is perceived positively, and the other one working as the human controller. This is a costly start for involving two professionals, but we consider it necessary due to the characteristics of ASD kids —particularly, the intense frustration and rejection they may experience in the face of any person, object or activity that they find unpleasant.
- Once the child has fully accepted the avatar, the subsequent sessions could take place with a single therapist, in charge of controlling the interaction through his/her voice and gestures.
- At non-critical points of the therapy, the avatar can be just one more intervention tool at the child's disposal, controlled by an adult without specific training (though properly instructed by the therapist).

Halfway between the models of the last two points above, we can foresee a scenario of technological implantation in which the therapists limit themselves to designing an interaction script for each therapy session with each kid, and delegate its execution to the controller of avatar-mediated interactions, seen as an entirely new professional profile. Especially in developing countries like Ecuador, therapists are a scarce resource, relatively expensive and with very little time available, whereas avatar controllers would have a lower qualification (even requiring a certain specialization in ASD therapy) and therefore could be more abundant and cheaper. Using AI to assist in the generation of those interaction scripts (again, to optimize the therapists' time) is still an open research problem, similar to one that we have approached in the area of speech and language therapies [74].

VIII. FUTURE WORK

Based on the results of the study presented in this paper, we consider it necessary to increase the number of avatars including, in addition to ethnic features, other anthropomorphic features. Although the majority of Ecuadorians are located within the mestizo ethnic group, within this group there are diverse variables that make it difficult to have a generalized image that fits everyone. This was reflected in the results of the variable "Similarity with peers", where most of the participants agreed that the avatars did not really resemble close people. We believe that the results could be improved by using a greater number of models for each ethnic group so

that, in addition to choosing an ethnic group, the participants can choose a model with which they feel most identified at the anthropomorphic level. We would also take advantage to incorporate avatars with characteristic indigenous and montubio clothing, since these groups form a relevant part of the Ecuador census.

Likewise, in the next stage of the project we intend to delve into another facet of personalization, considering the restricted interests of children with ASD. The insertion of the RIs in the avatars will be done indirectly, so that the avatar selected for the interaction has elements that are discreetly related to the RI (e.g. through a certain illustration on the shirt). The objective is to make ASD children feel identified with the avatar and break the barrier of interaction thanks to the common theme, but without this becoming a distraction.

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In loving memory of Rosario Pacheco.

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